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on Vehicular Communications

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In This Issue

1954 FIFTH ANNUAL MEETING OF PROFESSIONAL GROUP AT HOUSTON, TEXAS

1954 WESTERN ELECTRONIC SHOW AND CONVENTION

GROUP CHAPTER CONTRIBUTIONS

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IRE TRANSACTIONS

on Vehicular Communications

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Wescon

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* Presented before the Washington, D. C., Professional Group, October 28, 1954.

MANAGEMENT OF COMMUNICATIONS IN INDUSTRY

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The subject of Management of Communications in Industry is both timely and important. It is timely because confusion has arisen with respect to a number of policy matters having to do with the procurement, operation, and maintenance of communication equipment used by industry. It is important because policy decisions being made currently will, in the future, effect the continued ability of industry in this country to obtain the most versatile and reliable communications to serve industrial needs.

The spectacular rise of mobile radio systems serving industries in this country is little short of phenomenal. The importance and, in many cases, the absolute necessity of vehicular communications to present-day industrial activity is not a matter for argument. It is a well-established fact that vehicular communications together with long-established methods of communication are essential to the efficient conduct of modern business in this nation.

The newest communication tool available to industry in the post-war period is microwave communication and it, too, is following the pattern of growth of vehicular communications.

American industry today finds itself in the very desirable position of being able to depend upon its own initiative and its own devices to supply its communication needs. This fact has given rise to discussions throughout the country of the position of the common carriers and private industry as to the procurement and operation of communication facilities. The discussion has reached such proportions that it is desirable for all involved parties to re-examine their position and policies.

The principals in this discussion appear to be: The User Group; the Manufacturers who supply equipment for industry's communication needs; the Common Carrier people whose business it is to sell communication services to the public and industries; and finally, the Federal Communications Commission whose duty it is under an Act of Congress to regulate the application and use of communication facilities in the interest of the general public.

One purpose of this paper is to summarize and discuss some of the views of these several interests.

> First, in the hope that from the industrial management point of view some clarification of the issues involved will result; and,

Second, to place before us the information necessary to plot an intelligent course of action through the seeming maze of facts, inferences, and doubts which now cloud the future of industrial communications, particularly in the much over-crowded radio frequency spectrum.

A quick look at the industrial communication picture develops these significant factors:

1 - Statistics show the tremendous growth of communication in the United States. Millions upon millions of dollars of capital investment - and the figure is growing steadily - are being made in communication equipment both by industry for privately-owned facilities and by the common carriers to meet the increasing demand placed upon communication facilities by the nation's economic and social growth.

2 - Technical developments in the communication field come in rapid-fire order both in the field of fundamental development of new or improved communication facilities and in the adaptation for communication purposes of techniques used in other electronic fields.

3 - Industry is continuously faced with the necessity of meeting rising costs by effecting production or operating economies and by increasing speed of operation in order to meet competition and supply the market demands. These two factors alone account for the principal impetus underlying the phenomenal growth in amount and complexity of communication facilities used by industry.

4 - It is said that we are now in a second industrial revolution. The first was mechanization of industry. The second in which we have gone well beyond the formative stage, is "automatic control" and this causes a rapidly rising burden on communication facilities. In this sense, we define Communication as comprising both voice and record communications; the latter including supervisory control, telemetering, automatic control, facsimile, teletype, and the latest brain child, closed-circuit television.

With such a diversity of industrial communication requirements, it is obvious that the industrial communication engineer, his department and staff, must be qualified in these several fields, in addition to the longer established responsibility of furnishing voice communication facilities. The industrial communication engineer is a man of many coats, technically. In

addition, since an important phase of his work is in a field which might be described as lying in the realm of public property, that is, radio frequencies, he must not only be aware of the changes and requirements within the industry he serves but must be equally cognizant of the responsibilities to regulatory bodies and the necessity of coordinating the planning and operation of his own facilities with those which his particular industry shares with the public domain.

Attached to this paper as Appendix I, is what might be considered a job analysis of an industrial communications department. It is common industry practice in these days to subject jobs to analysis for the fixing of responsibility and the determination of the necessary authority to back up the job requirement. One without the other makes the job a fiction in the sense of effectiveness.

Since we are discussing Management of Communications in Industry, it is important to state in specific terms precisely what sort of job is to be managed. Taking into account the general factors thus far enumerated as they reflect upon the power industry, which I represent, Appendix I might be considered typical of the responsibilities of a power system communication department.

I shall not take the time to read the analysis here, but, in summary, in simplest terms, these responsibilities boil down to four general categories:

1 - Those having to do with internal company responsibilities and policies;

2 - Those bearing upon action and policy of governmental regulatory agencies;

3 - Matters of policy and practices of communication common carriers and their relation to the requirements of the particular industry;

4 - Responsibility of active participation in national and regional communications committees and associations through which industry needs and policies are voiced and coordination of mutual interests effected.

Since the industrial communication job is involved in internal and external responsibilities, both of which have an important influence on policy and economics, it is sound policy to centralize all communication activities in one department where responsibility and authority are fixed and direct control effected. Maximum economy and assurance of an integrated communication system to serve all phases of the company activity are the principal objectives of such centralization.

In simplest terms, a communication department is a service organization having responsibility to all departments of the company. As such, therefore, it is desirable that:

1 - Communications be a department, not a subgroup in a department whose major responsibilities lie elsewhere.

2 - Responsibility and authority be centralized and direct.

3 - The Communication Department should be far enough up in the management scale to assure that it is kept fully informed of company planning and operating problems.

4 - Contacts with outside communication interests such as the common carriers and FCC, both of which require uniformity of approach as a prerequisite for harmonious and profitable relations, should be centralized.

5 - Finally, for the communication department to do its job economically and without delays and misunderstanding, it must have direct access to the policy decision level of the company. Otherwise, second, third, or sometimes fourthhanded transmittal of communication problems to management results in loss of time, misdirection and increased cost simply because the final presentation of a problem lacks the completeness available only from the specialist in the field.

From time to time, all of us have been subjected to the argument that the industry which we represent is in business to make mouse traps or whatever product concerns us. The common carriers are in business to furnish communication services. Therefore, we are told, let the common carriers furnish the communication service since they are best-equipped and best-engineered to do so. The inference is that, first, a communication department in industry is an unnecessary expense and burden and, second, that the common carriers are in the position to eliminate this "unnecessary burden" and furnish all the communication requirements of industry in the most economical manner.

It has been the experience of many organizations who utilize common carrier facilities either in part or exclusively that the organization must also maintain its own department charged with the responsibilities indicated in Appendix I in order to satisfactorily work with the common carriers if the leased facilities are to function satisfactorily and that the greatest flexibility is to be obtained from the standard forms of communication offered by the common carriers.

It has also been the experience of those same industrial organizations that they must frequently insist upon modification of policies and practices of the common carriers to fit their peculiar needs in order to effectively use the common carrier facility.

These same organizations early in their experience found that actually there are two types of common carrier facilities - those which adequately serve the needs of the public generally and those which have been modified or can be modified in order to meet the specialized requirements of industrial use. This fact is particularly true in the power industry and necessitates the continuance of an active and well-informed communication organization to obtain the proper services.

The fact that industrial communication requirements frequently differ materially from the general public class of communication is sufficient argument to set aside any allegation that industry should look to the common carrier exclusively for its communication services because it is best suited to furnish it.

From the industrial point of view, particularly in those industries such as the power industry having, as it does, a direct responsibility to public health and safety, it is the belief of many managements that there is no such thing as <u>THE</u> Communication System. Rather, there is a growing tendency to adopt a number of basic communication systems which act to supplement each other, and, by the division of communication circuits between several methods of routes, thus obtain the maximum reliability and continuity of service. This statement obviously includes both common carrier facilities and privately-owned facilities. It most certainly means interconnection of the two.

The right of choice as to how the communication job shall be done - who shall do it - and what facilities will be used is a basic concept of policy which must govern the relations between the common carriers and industrial users of communications. I am pleased to say that in the electric utility industry, this basic concept of negotiations between the two industries has resulted in more flexible policies and in making available heretofore unobtainable facilities.

Through a period of years a substantially representative group of the Interconnected Power Systems have met periodically with the common carriers to discuss the mutual problems arising from the industry's desire to utilize to the fullest extent practicable communication facilities available from the common carriers. Ways and means of expanding the policies of the common carriers so as to make heretofore unobtainable communication facilities available for use by the industry have been explored and affected. Criticisms of the policies and practices have been frank and forthright, with the general result that the right compromise has been found under which the common carriers can supply their services and the industry can accept them - again, on the basis of the industry's fundamental right of election in the final analysis as to whether the job can best be done by private investment or on a leasing basis.

Industrial communication management is listening with a great deal of attention and with some alarm to the pronouncements of common carrier representatives, manufacturing representatives, the Federal Communications Commission and others, concerning policies and practices revolving around leased communication facilities, particularly in the field of vehicular communications. There are many in industrial management positions who are concerned with the future situation of the several industries having frequency allocations under present rules and regulations of the Commission, when considered in the light of leasing their vehicular service from the common carriers.

Industrial communication management is also concerned with the future aspect of microwave communications as a means of supplying bulk communication requirements at an economical cost.

Industrial management is aware of allegations to the effect that if the practice of leasing radio communication facilities from the common carrier is continued and expanded, that eventually we face the question as to whether or not special frequencies should continue to be set aside for industrial radio usage.

Questions are being asked concerning the charges of the common carriers and their accounting procedure in the sale, acquisition and maintenance of radio systems.

Manufacturers are complaining about alleged unfair trade practices in negotiations for contracts to supply communication facilities to industry.

Industrial communication organizations are complaining that they are not being consulted before policy decisions are made by management as a result of high level negotiations with the common carriers.

Industrial managements, under the pressure of business competition and the necessity for rapid expansion of production facilities requiring large capital investments, are inclined to more critically examine the best use of a capital dollar; that is, whether a capital dollar should be invested in production equipment rather than in service equipment such as communication, with the result that the service facilities would be obtained through leasing arrangements wherein the capital investment for equipment is borne by the common carrier furnishing such services.

The motivation behind all this welter of self-interest, over-enthusiastic sales promotion, and competition for communication business boils down to what appears to be reasonable and proper business policies. The area of disagreement lies principally in how these policies are implemented and carried out by respective representatives of the parties involved:

1 - Manufacturers are interested in expanding markets;

2 - The common carriers are interested in maximum use of their facilities and expanding revenues;

3 - Industry (the user) is seeking economical methods of meeting expanding demands for service and betterment of service;

4 - The Federal Communications Commission, sitting in the middle of all this discussion, is quite properly concerned with:

(a) Administration of the law
(b) Tariffs

5 - Finally, the User Group insists upon its right of choice of service methods and opposes any policy, which directly or indirectly, through frequency allocation manipulations tends to limit or remove this right of choice.

The Commission is concerned, and has so stated clearly and emphatically, that irrespective of management decision as to how it acquires its communication facilities, it is responsible under the law for the operation of that equipment. Without regard to any statements allegedly made by the supplier, industry is wholly and completely responsible for the operation of its radio facilities. It must at all times have access to the equipment supplied, and it must, for its own protection under the law, actively assume and carry out its responsibility to see to it that the radio facilities meet at all times the Federal Communication Commission's Rules and Regulations. There can be no delegation of this responsibility by contract or by any inference, direct or indirect, that the supplier is assuming that responsibility. Misleading statements relative to responsibility, if made deliberately in order to promote sales, is a dangerous practice which cannot be condoned. Management's wisest course is to see to it that service contracts not only spell out the licensee's responsibility but, additionally, specifically provide the necessary access to property and other physical means for discharge of responsibility.

As to the matter of future loss of frequency spectrum space resulting from increased use of leased services, the argument, to some management people at least, appears rather farfetched. The need for private frequencies for certain industrial radio services is established in the records of the Federal Communications Commission and allocations have been granted thereon. The fact that equipment to furnish this service may be obtained by more than one means is not a point of issue as to the present or future need of the private frequency. The right of choice as to who supplies what equipment is a policy decision that lies within industry and wholly outside the jurisdiction of the Commission. I should add here that matters pertaining to rates and tariffs applying to radio communication service to industry is properly a matter for Commission consideration. For that matter, it is also a matter for industry's consideration and frequently is a basic factor in the decision as to whether the industry will lease the facilities or invest its private capital.

Whether or not there are, in fact, unfair practices current in sales promotion, I leave to those authorities who are concerned in this phase of the problem. I would only say that if there were not, it would probably be unique in the history of commercial development and activity.

Industrial management's concern lies in the field of obtaining the maximum communication facilities for the minimum annual cost. If agreement could be reached following general policy principles, much of the present confusion and misunderstanding can be avoided.

1 - The basic right of choice as between leased or privately-owned facilities lies exclusively with the User Group. As a necessary requisite for exercise of this right of choice, the users must insist upon there being no tampering with frequency allocations.

2 - The User Group must negotiate its contracts, where such are involved, in a manner to fully meet its obligation under the law and the Federal Communications Commission's Rules and Regulations.

3 - Communications problems and policies should be exposed to the light of thorough analysis by fully informed industrial communication personnel prior to final policy decisions on the part of management; and

4 - The media of national committees and direct negotiations with the common carriers should continue to be fully utilized for the promotion of mutual interests and settlement of policy differences. Industry support of national and regional communication committees, particularly in the field of frequency coordination, is essential to the future health of industrial radio services.

SUMMARY

Where millions of dollars of capital investment and similar amounts for leased services are involved, it is understandable that strong pressures arise to garner in the industrial communication dollar. The simplest and most effective means of protecting the communication dollar is the maintenance of company communication departments of a nature which will keep its management fully informed of the progress of the art, of the broad aspects of the problems in the radio frequency spectrum, and expertly analyze the economics involved in obtaining, operating, and maintaining the diversified communication networks

required to meet the needs of industry. If the communication department of an industrial organization is to prove worthy of its assignment it must provide its management with the best communication network, selecting from all forms of facilities and services available to it, those which in combination best meet the specific needs.

Management can expect its communication department to render this type of communication service only if it delegates the proper responsibility and authority and acts on the recommendations of its communications organization.

Communication can be expensive. It can be an important part of production costs. It can be wasteful of people's time and effort. In some cases it can be an unmitigated nuisance.

Nuisance - liability - expense - it's an absolute necessity for the conduct of business. Industrial communications in the aggregate represents millions of dollars. The administration of the investment and operating expense of communication warrants the most careful attention on the part of management and, if given such, will make its proper contribution to economics of operation and effectiveness of service to the public.

APPENDIX I

MAJOR RESPONSIBILITIES OF COMMUNICATION DEPARTMENT

1 - Be responsible for planning, engineering, maintenance, standards and procedure activities involved in furnishing adequate, reliable and economic communication facilities to meet the specific requirements of all departments of the company; coordinate such requirements with overall company operations in order to maintain an integrated communication system.

2 - Supervise contracts and agreements; coordinate engineering requirements, communication practices and construction standards with those of commercial telephone companies with whom the company may be interconnected for the purpose of furnishing leased communication services and facilities.

3 - Act as authorized agent for the company with respect to the negotiation of contracts and agreements and the procurement of leased facilities from commercial telephone companies. Confer with manufacturers' representatives, and consulting engineers to obtain, furnish and exchange information and to discuss communication facilities, engineering operation and maintenance problems.

4 - Confer with representatives of the Federal Communications Commission to keep informed of FCC licensing, rules and regulations affecting industry radio operation; prepare, submit, and follow up on all applications for radio stations and operator licenses.

5 - Participate in professional society work, radio coordination groups and engineering conferences to keep informed of, formulate and exchange information on developments in telephone, radio and other communication activities as applied to policy matters affecting company operations.

6 - Initiate, supervise and conduct technical investigations, field surveys and tests involving communications engineering. Analyze and test new communication equipment for possible application. Conduct traffic surveys; make performance, efficiency and cost studies leading to improvements and economies in the communication system.

7 - Prepare budgets, maintain files on communication equipment, costs, procedures and standards; interview job applicants, be responsible for employe relations, welfare and compensation and settlement of complaints and misunderstandings.

THE COMMUNICATIONS ENGINEER'S ROLE IN AMERICAN RAILROADING

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When Lou Kearney asked me if I would present a paper on the Communications Engineer's role in American Railroading I wondered what I might discuss that would have universal interest. There are so many fields of communications and electronics incident to railroad operation that it is difficult to do real justice to any particular one in 20 or 30 minutes. For instance, the problems encountered in the mitigation of electrolysis U. G. cable plant is an important part of Railroad Communications Engineers' work on some railroads, while not important at all on others. Pole line design, wire crossings, power line parallelisms and conflicts, inductive coordination problems, telegraph and telephone transmission, radio, radar, and microwave all are incident to and part of Railroad Communications Engineers' everyday job. Therefore, and with your kind indulgence, I will endeavor to give you a general resume of what communications means to railroading and how the Communications Engineer has met the problem and grown with the job, what his problems are today and what his proposals embrace for the future.

The larger and more complicated railroad operations become, the more dependent management and personnel become upon communication facilities in order to know what is taking place and to initiate the orders and actions necessary to keep trains and traffic moving safely, efficiently and economically. Without a continuous flow of intelligence pouring over carefully established channels of communications, railroads could not perform the tremendous service expected of them. Some railroads operate as much as 15,000 miles of track. Consider the broad functional area as well as the technical activity incident to such operations. All this vast operation must be controlled to a degree of smoothness and efficiency of a perfect mechanism working under the trained eye of a master craftsman. To accomplish this the railroad industry has had to take each improved service afforded them by the telephone and telegraph and integrate these advantages into all phases of operation and service. To further this end the railroad industry has reached out into other fields and adopted microwave, electronic signalling, radar and in some cases even television to speed up the many operations involved in handling long freight trains safely and expeditiously. This constitutes a development of the most profound significance.

Modern communications is the nerve center of the railroad system from the standpoint of intelligence and control. The exploitation and utilization of communication facilities as applied to railroading and the ability to instantly visualize the ever increasing importance and possibilities such facilities play in railroad operation is the job of the Railroad Communications Engineer.

In the early stages of railroading, communication was immediately recognized as mandatory to operation. Naturally the potentialities of Morse telegraphy were recognized and in 1851 Charles Minot of Erie RR handled the first train order over neutral Morse telegraph circuit. Two years later duplex telegraphy was made available by Gintl; Thomas Edison made quadruplex telegraph possible in 1874. While quadruplex telegraphy has disappeared, simple Morse circuits are still used at many points on some railroads for train order and message business. Duplex telegraph circuits are abundantly used on railroads throughout the nation to handle printer service on a full or half duplex basis. Over and above these various combinations of dc telegraph is the carrier telegraph for printer service. Today many railroads employ thousands of miles of both FM and AM carrier telegraph for regular message business, train reservations, train consists and manifest reporting.

Today, many railroads use thousands of miles of both FM and AM carrier telegraph for regular messages, train reservations, train consists and manifest reporting. The choice between AM and FM carrier telegraph must be given careful consideration since both systems afford reliable high-speed transmission, and except for the noise advantage FM has over AM, the choice depends upon the particular application. When circuits (generally carrier) have low noise level, poor frequency stability, and no rapid level fluctuation, AM systems would tend to operate more satisfactorily. Systems (generally carrier) that are subject to considerable noise, level variation, but

that have good frequency stability, would operate better with FM carrier telegraph. The Communications Engineer must be familiar with the various types of service, their over-all effect on operations and the cost for a complete unit compared with that of similar equipment built by railroad forces. Upon his decision may rest the success or failure of a costly project involving thousands of dollars.

As an example, we were to replace ten duplex sets at a particular location on our road. The cost of each of these units amounted to $425 complete, but by arranging with the manufacturer to build the sets ourselves, we were able to save approximately $100 per set, or $1,000 on the project. These and other similar savings are part of the service rendered by the competent Communications Engineer.

Not long ago, my railroad initiated a mechanized car reporting system for consist and manifest reporting, to simplify car accounting and to produce a more adequate record of car movements. Before this system could be installed, the entire railroad had to be surveyed in order to approximately locate the important points where additional teletype facilities and equipment would be needed, and to determine the cost and means of obtaining the new equipment. Before the system of mechanized car reporting was placed in service the Communications Department was called upon to engineer, rearrange, purchase and install approximately 6,000 miles of carrier telegraph along with several hundred miles of physical telegraph circuits. In addition, five telegraph offices had to be completely rearranged and redesigned to accommodate additional printers, transmitter distributors, non-typing and typing reperforators and special IBM machines designed to take cards arranged in train order and convert the information to tape for transmission to the next terminal. Telegraph patching facility, loop operations, and power requirements had to be provided since the equipment must be arranged so as to provide maximum utilization. In some of the larger relay offices a portion is generally reserved exclusively for switching operations separate from local sending and receiving positions. Circuits designed exclusively for mechanized car reporting must be capable of handling continuous transmission without interruption since integrated data processing or punch card technique could not be applied in the sense that it is presently being used. The problem of lighting, heating and ventilation must be considered; while the Communications Engineer is not directly concerned with the construction of these facilities he must be familiar with all phases of the project since each one would have an effect on the over all success or failure of the operation.

You may wonder why in the midst of all this unprecedented modernization of telegraph facilities we continue to use simple Morse circuits. I might answer this question by saying that these short haul Morse circuits provide economical service on branch lines and between stations on the main line. They are also used occasionally for emergency dispatching purposes. The quantity of traffic handled over them is generally small, and when personnel are available and properly qualified it is expected these circuits will stay in operation for some time to come.

As to the future of the over-all telegraph plant I may say that it is ever expanding; additional carrier circuits are being added each year as the railroads continue to integrate mechanized car reporting systems. While our present plant provides for the most part the operation of printer equipment on a 60 WPM basis, it is not unlikely that we may go to 75 WPM in the not too distant future, as traffic continues to increase. We have also considered the use of 100 WPM printers for operation on short local circuits for the preparation of waybills between freight station and yard office. Carrier telegraph circuits are being introduced into the field of CTC operations on railroads and, since carrier telegraph circuits are more abundant about the railroad plant, they render themselves more readily for alternate use and provide considerably more flexibility in operating Centralized Train Control from distant locations. The success of operating Centralized Traffic Control over communication facilities is the result of the combined talent of the Communications and Signalling Engineers.

To reach into the more distant future as regards the proposition of expansion of telegraph circuit activity, I might say that many of the larger relay offices presently being handled on a manual basis will be arranged to handle message service on a completely automatic basis. A further but more distant arrangement may be to some day use many carrier telegraph circuits as a medium of transmission to furnish information to giant and complex computers. Such machines are capable of handling up to 3600 items per minute and, if the information from various divisions were combined and sent to a central point where one of these machines were located, it is feasible to assume that one machine

could handle the work of several hundred people and provide the answer to many problems in a matter of minutes. The application of facsimile to the communication plant has been given serious consideration by many railroads for service between local points.

TELEPHONE

Up to now I dwelled principally upon the Communications Engineer's problem and relations to telegraph facilities. I would like to now discuss the tremendous impetus that improved telephone communications have had on present day railroad operations. Between 1884 and 1900 the art of telephony was developed to the point where a large number of telephones could be operated successfully on one circuit and during the same period three and one-half cycle selective signalling was developed. When this was accomplished railroad dispatching facilities were born.

The early Communications Engineer, along with the manufacturer, began the long development period which has brought us the excellent standards in communication by which trains are presently being dispatched. To the Railroad Communications Engineer the dispatching circuit is his most important piece of circuitry. All others may fail but when the dispatcher's circuit ceases to operate, trains are delayed or slowed down or may even be stopped. So long as the dispatcher can talk with way-stations or train crews he can keep the railroad operating and delays to passenger and freight trains can be minimized. You can therefore see the importance of such a circuit. The dispatcher's circuit is essentially a long party line. Some circuits where traffic is quite heavy are only 60 miles long, whereas in areas where the traffic is lighter the total mileage connected to the dispatcher would be somewhere near 500. Any station connected to such a circuit can be rung selectively by the dispatcher as it is desired. In order to ascertain that the signalling equipment in the way-station is operating properly arrangement is provided on the station selector to give the dispatcher an answer back while the bell is ringing. All phones connected to this circuit are of the local battery type. In the connection and design of such a long circuit where there may be as many as 60 to 300 phones on the same line, the Communications Engineer must keep many things in mind, some of which are as follows:

1. The over-all transmission from end to end and from one end to dispatcher.

2. The amount of ringing power necessary without resorting to extremely high voltage.

3. The number of ringing repeaters that can economically be installed to reduce the over-all ringing current at the dispatcher's office.

4. The effect of simplex circuits from the standpoint of noise, etc.

5. The amount of near-end crosstalk, side to side or phantom to side if phantom circuits are involved.

6. The effect of superimposing carrier on these circuits.

7. Patching facilities.

8. Telephone efficiency. Bridging loss, filter effects, etc.

The Communications Engineer must be able to devise methods such as were necessary during war periods when it became necessary to split a dispatching district because of increased traffic. At that time the manufacturer had not developed a method of selective ringing over a carrier system. The problem was given to the Communications Engineer and the result was an arrangement which permitted signalling over carrier channels. Today such devices are available commercially. Occasionally it becomes necessary because of economic reasons to close down a way-station; however, the dispatcher is still interested in knowing whether or not the train has passed this particular location. Here again several simple arrangements have been developed by the various Communications Engineers throughout the country to provide this information on a coded or non-coded basis, audible back to the dispatcher. The general trend today is to consolidate dispatcher districts as the operating divisions increase in size. By careful application of carrier, the voice frequency repeaters and by consulting with manufacturers on various problems relative to equipment, Railroad Communications Engineers are keeping pace with the ever-changing field of dispatching facilities.

When one speaks of long distance telephone circuits it brings to mind the facilities of A. T. & T. Co.'s Bell System, yet many railroads, especially those West, have long distance circuits commensurate with the Bell Plant. These circuits are in many respects replicas

of the Bell System, especially in the carrier equipment. Single channel carrier operating in the frequency band between 4 and 10 kc were the first to find their place on railroads around the mid 30's. Shortly thereafter 3 channel carrier was used. Today railroads use stackable type systems that can provide anywhere from 1 to 12 channels. For example, our railroad operates 3 channel carrier between Houston and El Paso and Houston and New Orleans, in addition to carrier systems to San Antonio, Dallas, Victoria and Lafayette. Some of these carrier channels are used exclusively for carrier telegraph and others are designed to operate on a speech plus basis.

The successful operation of carrier on existing wire facilities, especially the extremely long-haul type such as exist between Houston and El Paso on our road, is a challenge to the Railroad Communications Engineer. Let me tell you briefly what must be done before carrier can be operated successfully on railroad wire facilities. First, terminal and all repeater locations must be decided upon. By reference to tables and formulas the theoretical loss based on wet weather conditions can be estimated between terminals and repeater. This assumes that all irregularities resulting from impedance mismatches between open wire and cable be corrected by auto transformer, carrier cable loading or similar device. Transmission tests are then conducted to verify the theoretical values. Near-end and far-end cross-talk tests are made to discern if possible the effects the proposed carrier system may have on existing systems or if the proposed system will be subject to adverse cross-talk or noise. Since the proposed carrier is usually placed on the dispatch or message circuits, appropriate filtering of the way-station telephones must be considered. The Communications Engineer must be able to evaluate the results of his tests from the standpoint of cross-talk, attenuation, noise, absorption, etc., and to take advantage of frequency frogging or frequency inversion, if you please, to reduce the amount of slope equalization required to produce flat channel response. The end result of course is better circuit performance. The selection of type and make of carrier equipment is important and the matter of loop gain in terminal and repeater along with the type of regulators and method of signalling must be considered. Regulation in the carrier system is important to the Communications Engineer. You folks may prefer to call it A. V. C. Well it is essentially that plus a little more. Some regulators provide slope equalization as well as regulators, that is to say they automatically compensate for the first derivative or change in line attenuation with frequency during dry weather. In addition some regulators are equipped with networks that provide "twist" so to speak. "Twist" in the carrier language is a term applied to the second derivative or changes in the slope of the attenuation curve due to wet weather. Whether the carrier system operates in frequency band between 4 and 35 kc or 40 to 152 kc, the problems confronting the Communications Engineer are similar except that high frequency systems are more susceptible to cross-talk and absorption peaks. Today however, by the use of compandors it is possible to get approximately 22 db cross-talk advantage and make possible operation of high frequency carrier systems on circuits, which would otherwise require expensive retransposing to keep cross-talk within acceptable limits. Obviously the application of compandors to carrier channels is one of extreme importance since the cost of retransposing a line from a 3 kc pattern to a 30 kc pattern amounts to approximately $90 per mile, whereas transposing from a 30 kc pattern to "J" transposition scheme would be approximately $150 per mile.

The present trend among railroads in long distance telephone is toward toll dialing between major division points. The principal advantages are reduction in the number of operators necessary to process calls and the greater rapidity in distribution of these calls. On the other hand it is generally necessary to increase the number of trunks between two given points. Here the Communications Engineer must decide on the relative economics involved. Reducing operators is certainly a savings; however, adding trunk circuits may be costly, depending upon the condition of the underlying physicals, the number of carrier circuits in present operation and the number of additional circuits required to handle the increased traffic efficiently. The problem of switching on a through and terminating basis must be considered and especially if the switching equipment is to be wholly owned by the railroad. For example, in multi-channel carrier systems employing dial facilities, the carrier signalling panel on each end per channel must work into a device known as a dial applique panel. This unit may be designed to handle simple dial

functions covering control and supervision or it may be designed to handle several functions including control, supervision, flash back busy, network switching and radio transmitter control.

If it is proposed to employ several multi-channel carrier systems in a toll dialing network, arrangements must be provided to maintain appropriate transmission equivalents especially when dialing through one division point to another. Common practice is to set the 1000 cycle level at the hybrid line jack for 3 dbm and then insert 3 or 4 db in the through and terminating tie trunk equipment. Station to station calls then equate to 6 or 7 dbm. When a through call is placed the operator connects the two carrier channels to each other via the through jacks; this removes the 3 or 4 db pad, whichever has been inserted, and the net loss through the office remains at 6 dbm. Such an arrangement must be provided for on an automatic basis when going to inter-toll dialing on the railroad.

RADIO

Over and above the application of telegraph and telephone to modern day railroading the Communications Engineer has had to cope with the ever increasing impetus the application of radio has had on the railroad industry. As early as 1914 tests were conducted to determine the possibility of an induction system on an eastern railroad. It was not successful, however, due in part to high noise level and probably insufficient knowledge in circuit design. It was a step, however, and tests of various degree continued throughout the country on several railroads. It was not until after World War 2 that radio application to the railroad industry became of any significance. Here again the Communications Engineer working with the manufacturer, making field tests covering transmission, power output, receiver sensitivity, frequency stability, and above all the ability of the equipment to withstand the vibration and shock encountered, helped to develop the present day set. Today several manufacturers offer excellent gear for train radio service all of which is the end result of collaboration between Railroad Communications Engineers and Manufacturer.

Many railroads today are rapidly expanding the application of radio to engine, cabooses, yard and way-station service. The end results of such installations manifest themselves in less terminal time, reduction in delays while on the road and also contribute tremendously to "pooled information"— that is to say, everyone is aware of what is taking place. In addition to these, the use of radio in railroad operations provides continuous access to moving trains as a safeguard against accidents.

For those railroads completely equipped with radio the problems are essentially those of maintenance and refinements of application, such as an ingenious arrangement worked out by one railroad communications engineer that provides for operation of power switch to allow a train to enter a yard or hold the main track. The entire operation is performed by the use of 2 audio oscillators in conjunction with a small portable pack set among other equipment. As time goes on there will be many other such useful applications of radio. Railroads not equipped with radio face the problems of testing for propagation and deciding upon a particular manufacturer. The Communications Engineer's decision usually comprises the question of economics, performance, durability and future arrangement.

Microwave systems have not as yet found their way into general railroad application except in a very few cases. There are many reasons for this. It is still more economical to use wire line carrier when such lines are available in place of microwave. Another reason has been the constant state of flux the art has been in which included the never ending argument as to the relative merits of the different types of channelizing or multiplexing. On large projects the cost of propagation tests are high; without such tests it is practically impossible to design and engineer a system.

The Communications Engineer, upon deciding to install a microwave system, must consider the relative economics, advantages and disadvantages of a particular application. The selection of multiplexing equipment will be governed to a major extent by the type of service involved. I would venture to say that the railroad industry might prefer frequency division to other types of multiplexing such as FM, P. T. or double side bend transmission because wire line carrier of suppressed single-side-band type could be arranged to work into the microwave system as well as the wire line. Also, the modulation band width for a given number of channels employing frequency division is considerably less than for a similar number of channels employing pulse systems. Microwave systems will eventually find considerable application in the railroad industry and especially

So on those railroads whose communication lines are subject to frequent prostration as a result of storms. The Railroad Communications Engineers are keeping a constant vigil on the various systems offered by the manufacturer and are ever ready to make use of the advantages offered by this equipment when possible.

The Railroad Communications Engineer has worked closely with the manufacturer in the development and application of radar applicable to wire lines as a fault detector. The device provides a means of detecting shorts, opens, grounds, etc., on open wire lines up to 200 miles in length. Further use of radar, so to speak, is employed in a device which makes use of the "doppler" principle for checking the speed of trains on restricted curves. It is expected this device will find many other applications in the railroad industry.

So much for the general picture of the Communications Engineer's role in railroad industry. Now for a few moments I would like to give you some of the Communications Engineering problems incident to the construction of one of the South's largest push button gravity switching yards presently under construction by Southern Pacific RR - T&NO Lines at Houston. This yard will be able to perform the classification switching necessary to accommodate the movement of some 6000 cars per day. After the general track and building plan was agreed upon, the Communications Department was called upon to provide sufficient communication to enable the entire yard to operate efficiently. To accomplish this it was necessary to provide 5 separate talk-back and paging systems throughout the yard employing 216 TB speakers and 40 paging speakers. Each of the 5 systems will work into separate consoles of various sizes. All consoles are wired together to provide low level communication between them. The entire cable plant is being placed under ground and only cable terminals will be above ground. It is estimated we will have approximately 120,000 feet of cable buried in the yard. Altogether the gravity switching yard will be provided with approximately 500 watts of paging power. Supplementing this a small automatic PAX will provide additional communication between many of the points in the yard and general office.

At the west end of the yard on each side and also in the middle of the yard, car checking stations are located. Men in these stations will be provided with special telephones that can be connected to a dial line or to tape recorders located in the general yard office approximately a mile away in the vicinity of the top of the yard. There are seven tape recorders available, any one of which can be accessed by the men located in the car checking stations by merely lifting the receiver from the hook and depressing a button once. When the recorder is accessed it sends a low audible tone to indicate it is ready to record; also it is made busy to all other lines by virtue of the automatic switching equipment. The checking station can now begin his recording of the train as it passes his station, stopping and starting the recorder by means of a push button located in the hand set. Upon completion of the recording the checker hangs up the phone.

The recorder, while still remaining busy to all lines, rewinds itself to the start position and signals the transcribing operator that it contains information on tape for him. The transcribing operator, upon seeing the light, operates a key which connects the output of the recorder to a head set or to a loud speaker and proceeds to transcribe the message, starting and stopping when necessary by means of a foot switch. He may also rewind the recorder by operating a key for that function. Upon completion of the transcription the transcribing operator operates a key marked "reset". The operation of the reset key causes the recorder to rewind itself to the start position, extinguishes the signalling lamp, returns the recorder to the bank of recorders and removes the busy at the same time making it available for future use. In addition to the above, all yard and humping engines will be equipped with radio; also the various towers will be equipped with radio, and provisions have been made to remote control the tower radio from other important points throughout the terminal.

Another innovation made possible by electronics is in the situation confronting the Railroad Communications Engineer as a result of air conditioning and sound-proofing various towers and buildings. While such embellishments are excellent from the standpoint of health and comfort of the personnel involved they do present the problem of hearing train whistles, sounds, etc. taking place on the outside. Actually sound will be wired into the towers by locating loud speakers at strategic points throughout the yard and then

connecting them to an amplifier input. The output will be connected to a small speaker with suitable volume control.

While I have made reference to the Communications Engineer throughout the discussion I would like to say that the term be used in the broadest sense to include Superintendent, Assistant Superintendent, Electronic Engineer, and Supervisor of Communications since the greater portion of these men are essentially Communications Engineers, whose broad experience and application ability have made possible the extraordinary acceleration in railroad communication in past decades.

A MULTICHANNEL CRYSTAL OSCILLATOR

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Introduction

As a source of a multiplicity of crystal controlled frequencies, one may utilize frequency-controlled spectra obtained by the generation of narrow pulses at a crystal controlled repetition frequency. At VHF and even more so at UHF, this requires pulses of extremely short duration and of very large amplitudes. The pulse energy is spread over the entire frequency range from the fundamental to above the highest utilized frequency. Thus, most of the available energy is contained in the frequency band below the desired reference frequencies leaving only little energy in the utilized frequency range. The energy of all harmonics that are not simultaneously used is wasted. They may also fall into a critical frequency range and cause undesired responses, or their presence may result in unwanted frequency combinations with other signals.

The oscillator type described in this paper permits the selection of any desired one of an unbroken series of harmonically related frequencies without having the aforementioned disadvantages. It consists of two sections: A crystal oscillator operating at the fundamental to the desired output frequencies and an oscillator which is periodically phase-controlled by the fundamental oscillation such that its output frequency spectrum contains only harmonics of the crystal oscillator frequency. Frequencies that are not harmonically related to the crystal frequency are not generated. The oscillator operates simultaneously in the range of the desired output frequency and at the crystal controlled fundamental to it. This simplifies the circuitry such that only one vacuum tube, one quartz crystal and two tuned circuits are required to produce an output spectrum of high order harmonics. The spectrum energy is concentrated about the harmonic nearest to the frequency of the periodically phase-controlled oscillator.

Principle of Operation

Fig. 1 shows the circuit diagrams of two periodically controlled oscillators. The oscillator circuit at the left covers the 20 to 30 mc range in 1 mc steps. The one at the right covers the 250 to 900 mc frequency range in 5 mc steps. The crystal oscillator sections are of the Miller type, having a tuned circuit in the plate and the quartz crystal connected to grid and cathode. The phase controlled oscillator sections are of the Colpitts type. The feedback is determined by the electrode capacitances of the vacuum tube and the cathode-to-plate capacitor. The UHF tank circuit is paralleled by a network consisting of the tuned plate-circuit of the crystal oscillator section and a choke which makes the shunt impedance of this network high at the ultrahigh frequencies. The reactance of the grid capacitor is sufficiently high at the fundamental frequency to separate the tank circuit of the phase controlled section from the quartz crystal. A choke keeps at UHF the grid above ground potential. It is selected to be small enough to avoid upsetting the oscillation conditions at the crystal-frequency. The circuit diagram at the left gives an illustration of a series combination of the parallel-resonant circuits.

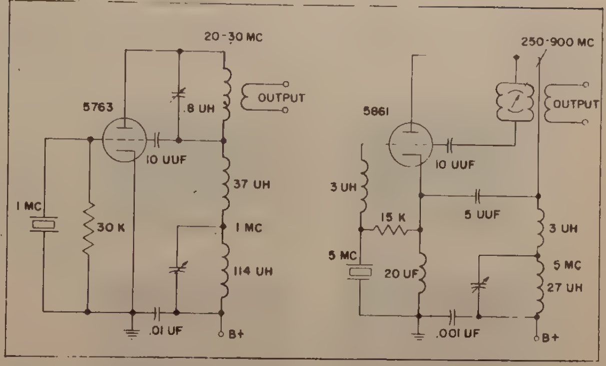


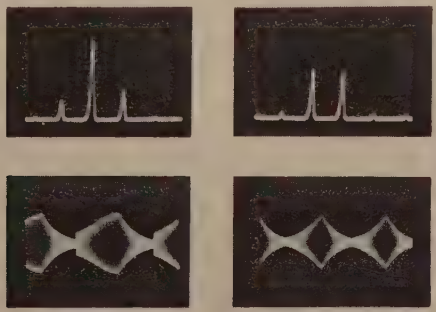
Fig. 1 – Circuit diagrams of periodically controlled oscillators.

The fundamental requirement for the simultaneous self-excitation of oscillations at two or more independent frequencies is that their frequency ratio is large enough so that for the operation at each one of these frequencies, all circuits tuned to the other frequencies are of negligible influence.

The phase controlled oscillator section is tuned to the desired frequency. It is keyed by pulses, generated in the crystal oscillator section. They bias the grid such that the generation of oscillations is restricted to the pulse duration. Thus, the pulse repetition interval is

divided into a regenerative and a degenerative period. During the initial part of the regenerative period, the oscillations build up exponentially. These oscillations decay exponentially in the degenerative phase due to the pulse controlled decrease of the transconductance of the oscillator tube below the value at which the phase controlled section is oscillatory. The time constant of the buildup function depends upon the negative resistance and upon the amplitude of the harmonics of the keying voltage in the vicinity of the oscillator frequency.

The operation conditions of a periodically phase-controlled oscillator are illustrated by the oscillograms of Fig. 2. It shows the output waveforms and



PPCO tuned to an integral multiple of the repetition frequency.

PPCO frequency halfway between two integral multiples of the repetition frequency.

Fig. 2 - Waveforms and output spectra of a periodically controlled oscillator.

the frequency spectra of an oscillator which was operated in the 5 mc range, in order to remain in the amplifier passband of the available oscilloscope. The phase control occurs at the time of the voltage step. The time interval between two successive voltage steps corresponds to a pulse repetition frequency of 100 kc. Tuning the output section to an integral multiple of the crystal oscillator frequency, one obtains the oscillograph at the left. It shows a faster build-up of the 5 mc oscillations than in the oscillogram at the right which describes the waveform obtained when the frequency of the oscillations in the time interval between two successive voltage steps is halfway between the frequencies of the two adjacent harmonics. If the regenerative period is sufficiently long, the oscillator amplitude will finally be limited due to the nonlinearity of the tube characteristics. The amplitude envelope of the output spectrum is peaked at the frequency at which the oscillator is free-running between two successive voltage steps. At the left the spectrum envelope is peaked at a harmonic of the keying frequency. At the right the envelope peak is located between two adjacent harmonics, resulting in two output signals of similar amplitudes.

It is essential that the output wave shape be periodic at the pulse repetition frequency. Otherwise the output would be that of a carrier which is amplitude modulated with the keying signal. If under that condition, the UHF oscillator is tuned to 499 mc, then its output would also contain this frequency. This would not give us the desired condition where the output contains only harmonics of the crystal oscillator frequency of 5 mc. Periodicity is most easily obtained if the oscillations disappear in the noise level before the next pulse arrives. Because of the exponential law governing the decay this would require a longer duration of the degenerative period than, in view of the desired bandwidth limitation of the spectrum envelope, is permissible. The oscillator may have oscillations of relatively large amplitudes at the end of the decay period. Their phase-control requires harmonics which are large in amplitude compared to these residual oscillations.

To obtain a minimal bandwidth spectrum, it is necessary to make the constant amplitude period long compared to the build-up and decay periods. In this operating condition, most of the energy is available at the desired output frequency; only a negligible part of the energy is contained in the adjacent undesired harmonics. It requires extremely steep buildup and decay slopes of the output waveform. To shorten the time constant of the decay, a low circuit - Q is required. Periodically loading the tank circuit with a pulse controlled diode, the constant amplitude condition can be extended over a large part of the pulse repetition period. At frequencies above 300 mc, however, little advantage is gained by the use of this method because of the lowering of the negative resistance during the build-up period and the reduction of the tuning range resulting from the addition of the diode.

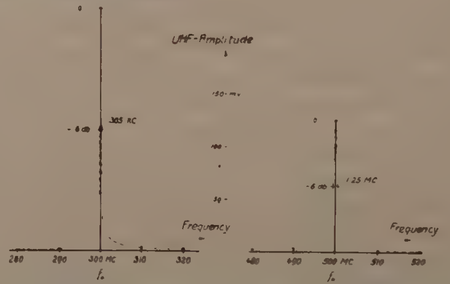


Fig. 3 - Output spectra of a 250 to 500 mc oscillator periodically controlled at 10 mc.

Typical output spectra of a periodically controlled UHF oscillator are shown in Fig. 3. They are generated by a 250 to 900 mc oscillator which is controlled at a repetition frequency of 10 mc. One amplitude envelope is peaked at 300 mc. The other spectrum was obtained tuning the same oscillator to 500 mc. At the lower frequency, the circuit-Q and the harmonic content of the keying voltages are higher than at 500 mc resulting in the reduced bandwidth of the spectrum envelope and the increase of the output at the desired frequency to about 1 mw.

The spectrum envelope is not symmetrical about the frequency to which the UHF tank circuit is tuned. The unsymmetry is caused by the frequency variation of the periodically phase controlled oscillation during the pulse repetition interval. Another effect of the frequency variation during the pulse repetition interval is the broadening of the envelope peak. It permits an increase of the long-time frequency instability of the oscillator circuit with little deterioration of the degree of suppression of the undesired harmonics. The relative accuracy of the output frequency is of course, completely independent of such frequency variations and is the same as that of the crystal stabilized fundamental frequency.

Restricting the spectrum bandwidth leads to increased requirements on the accuracy with which the oscillator has to be tuned to the desired harmonic. It is therefore important to know the shape of the spectrum envelope between two adjacent harmonics. To determine it, one has to vary either the frequency of the phase controlled oscillation while maintaining the crystal frequency or one keeps the first one constant and varies the frequency of the keying voltage. The results are shown in the oscillograms of Fig. 4 obtained with an automatically scanning receiver which permits the display of the input signal on a cathode ray tube screen.

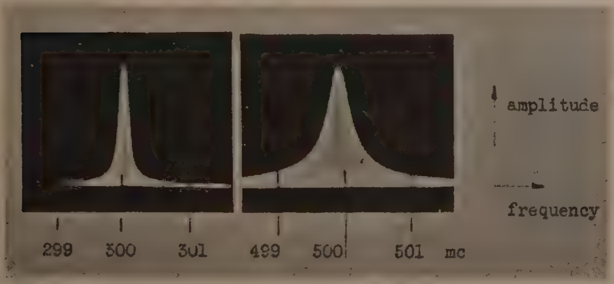


Fig. 4 - Spectrum envelopes observed at different settings of the UHF-oscillator tank circuit.

The X and Y deflection is proportional to the frequency and amplitude of the signal, respectively. The boundary between light and dark is the envelope which is observed during a sweep of the fundamental frequency of approximately 20 kc about the center frequency of 10 mc. The oscillogram at the left gives the relative amplitude of the 30th harmonic as a function of the tuning of the UHF tank circuit. When tuning the same oscillator about a center frequency of 500 mcs, one observes the envelope at the right. These oscillograms were obtained at different receiver sensitivities. At the higher frequency, where the energy is distributed over a wider band, the peak amplitude is only 1/3 of the amplitude observed when the same oscillator is tuned to 300 mcs. During a drift of this oscillator of up to 4 mcs, the adjacent harmonics remain practically unchanged in amplitude.

Frequency Accuracy

The required accuracy and stability of the phase controlled oscillator section depends upon the level of the undesired harmonics that is permissible for a specific application. A detuning of the oscillator from the frequency which is equal to an exact integral multiple of the fundamental frequency causes a decrease of the amplitude at the desired frequency. To keep the adjacent harmonics below 1/10th of the amplitude of the desired output frequency, the described UHF oscillator would, at 300 mcs, have to be accurate to ± 750 kc (± 0.25%). In order to maintain at 500 mc a 20 db suppression of the undesired harmonics, one can allow a frequency drift of approximately 1 mc toward the higher frequencies and, due to the unsymmetry of the spectrum envelope, of 2 mc toward the lower frequency side.

Applications

This oscillator is of advantage wherever it is desirable to generate directly, and without selective amplification, frequency components of a high harmonic order. For applications as the local oscillator of a receiver or the transmitter exciter of multichannel equipment, the spectrum-envelope bandwidth should be extremely narrow. Where the frequency drift of the phase controlled oscillator section approaches half the channel spacings, these applications may also require special modes of operation. In one operating condition, due to a small negative resistance, the build-up time-function of the output waveform is much longer when the oscillator is tuned between two adjacent harmonics compared to this build-up function at the correct tuning of the oscillator. In the other operating condition, due to a further reduction of the feedback, the output waveform has a long period of time-independent but strongly tuning-dependent amplitude. Under both conditions, the amplitude of the adjacent harmonic, toward which the phase-controlled oscillator-section drifts, increases very little until the resonance frequency closely approaches the frequency of this harmonic. Thus the oscillator, while being tuned continuously behaves as though it were electronically detented.

To approach the power output of a conventional crystal oscillator, the periodically controlled oscillator has to be followed by one stage of selective amplification. The resulting output spectrum is diagrammed in Fig. 5. It shows the amplitudes of the individual harmonics as observed in the output of a one-tube amplifier which is coupled to the 20 to 30 mc oscillator of Fig. 1. The zero db level corresponds to 3 volts on 50 ohms. This graph demonstrates the major advantage of the phase-controlled oscillator over conventional spectrum generators: The undesired harmonics are strongly suppressed.

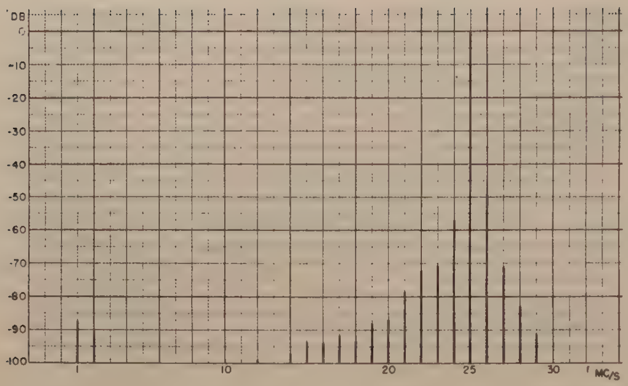


Fig. 5 - Output spectrum of a 20-30 mc periodi-called controlled oscillator which is followed by a one-stage amplifier.

The generation of a narrow band of frequencies in which the energy is concentrated, permits an extension of the frequency band in which a harmonically related frequency spectrum of useful amplitudes may be generated. An experimental model of a periodically controlled oscillator has been built that covers the 250 to 500 mc frequency range in 1 mc steps. Its photograph is shown in Fig. 6.

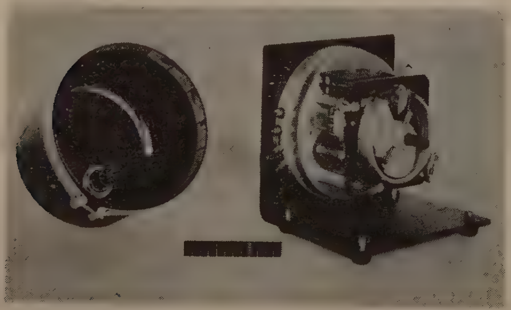


Fig. 6 - UHF Spectrum Generator, 250-500 mc (Experimental Model)

This spectrum generator consists of a General Radio Oscillator which has been modified by the addition of a 1 mc quartz crystal, a plate choke which is self resonant at the crystal frequency, and a few minor components. It was designed for the generation of a narrow-band frequency spectrum. As shown in Fig. 7, the minimal envelope bandwidth of its output spectrum is much broader than that obtainable at lower harmonic ratios. The power output of the 500th harmonic, 120 mv on 50 ohms, is orders of magnitudes larger than that obtainable from other harmonic generators of comparable simplicity.

Fig. 7 - 1 mc spectrum of the 250 to 500 mc spectrum generator, centered at 500 mc.

Acknowledgement

The contributions of Messrs L. Battersby, E. Christian and E. Conover are gratefully acknowledged.

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CITY OF HOUSTON VEHICULAR COMMUNICATIONS SYSTEM

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SUMMARY

This paper is a general description of the radio communications system being used by the City of Houston, Texas. As early as 1926, the first experiments in the use of radio for police work in Houston made use of a commercial broadcast station, which interrupted regular programs when necessary. Today, communications and electronic work for most city departments is done by this agency, although the division is a section of the Police Department. The operation of three F. M. transmitters and receivers into a single antenna, and the problems encountered with intermodulation are outlined.

TEXT

In August, 1952, the City of Houston completed a new Police Administration Building to accommodate the enlarged Police Department required by the rapid growth of the city.

The Department's communications equipment installed in this building incorporates some ideas received from many other similar organizations. It is not intended at this time to make an example of the equipment as the largest or most modern in any certain area. Rather, it is intended to call attention to the application of these ideas to a system which, we believe, serves the needs of the city in the best manner possible.

The Communications Division of the Police Department in reality serves as the Communications Department of the entire city government, being responsible for the operation and maintenance of practically all city electronic equipment. The main items included are: three 250-watt fixed radio stations; six 50-watt fixed stations for point-to-point and auxiliary use; a ten-channel radiotelegraph transmitter; 500 mobile units; television cameras and receivers, and quite a few speech amplifier installations.

The offices, most fixed radio equipment, and mobile repair shops are located at the Police Administration Building (Fig. 1) near the center of the city. This location was second choice to a separate building, which might have been situated in a less congested place; but the antenna was found to give good coverage of the service area.

Advance tests of the antenna site were made by using an aerial truck of the Fire Department with a test antenna on top of the 110-foot extension ladder. The hydraulic ladder was extended and raised after the antenna had been attached, making a quick and simple way to place the antenna above surrounding objects. Relative signal strength in the service area was then compared with other possible antenna locations.

The fixed transmitters (Fig. 2) are installed side by side in a soundproof room adjoining the control room, and are visible to the operator through a glass wall above the operating positions. A primary frequency standard is also located in this room, for checking the frequency meters for the fifteen different frequencies now in use. The main stations are in 24-hour service, with dispatchers for the three stations located in their respective buildings, namely: the Police Building, the Fire Alarm Building, and the Water Division Maintenance Building.

Operating frequencies for the transmitters are: Police 156.03 mc; Fire 154.31 mc; and Water (or Utilities) 153.41 mc. Their output is fed through cavity filters and a three and one-eighth inch coaxial transmission line to a single antenna with a gain of 6 db, on a 450-foot self-supporting tower.

A self-supporting tower (Fig. 3) was necessary because the congested area did not permit the use of guy wires. The geographical location required a design which would withstand a wind loading of sixty pounds per square foot on flat surfaces. Because of the possibility of hurricanes in this section and the resulting danger to the downtown area should the tower collapse, an extra safety factor was necessary.

Three coaxial transmission lines are installed on the tower, allowing two spares for auxiliary antennas. It was undesirable to return the lines to the base of the tower on the ground, since the transmitters are located on the sixth floor of the building; so a catwalk was extended 105 feet from the building roof to carry the lines to the eighty foot level. An electrically operated "spider" staging unit takes off from this catwalk to carry persons to the top of the tower and the antenna for maintenance and experimental work.

The method and problems encountered in operating three F. M. transmitters and receivers on different frequencies into a single antenna may be of interest. Since it was desired to install the stations all at one location near the tower, consideration was first given to the possibility of locating three separate antennas on the tower. Tests were made with the antennas mounted six feet apart in an equilateral triangle, with the transmitters working on the frequencies 156.03 mc, 154.31 mc, and 153.41 mc. Two cavity filters, with half db loops, were installed in each trans-

Fig. 1

Fig. 2

Fig. 3

Fig. 4

mission line in an attempt to prevent excessive desensitization of any one receiver when the other two transmitters were on. The combination of frequencies, however, turned out to be just right to be wrong! The greatest offender appeared to be the third harmonic of 154.31 mc and the second harmonic of 153.41 mc, producing an intermodulation product of 156.11 mc, which was only 80 kc higher than the frequency of the receiver operating on 156.03 mc. It was seen, that when modulation of 15 kc was applied to the two transmitters, the modulation deviation was also multiplied. In one case this amounted to 45 kc and in the other to 30 kc, with a total product of 75 kc which would enter the band-pass of a receiver 80 kc off. An additional cavity seemed necessary for the transmitter producing the interfering third harmonic; also, the radiation pattern of each of the three antennas was distorted too badly by the other two.

Since another cavity must be added anyway, it was decided to try a single antenna. This would allow the use of an antenna with a higher gain and should help compensate somewhat for the additional cavity loss. The intermodulation was reduced with the extra cavity, but was still objectionable; and the only real correction seemed to be to change the transmitter frequencies slightly. This was the final solution. The center frequency of the 154.31 mc transmitter was moved up by four kc and the 153.41 mc transmitter down by four kc, producing an intermodulation frequency of 156.13, which is 100 kc from 156.03. The center frequencies of the stations are accurately maintained, of course.

In the control room, the station operators are provided with three sets of modulation-frequency meters and three remote control panels, one set for each station. (Fig. 4) This furnishes constant monitoring of the dispatchers of the three stations and each of the three stations' frequency and modulation, as well as making possible the dispatching of mobile units on any of the three frequencies in emergencies.

A ten-channel radiotelegraph transmitter is controlled from the operators main position. (Fig. 5) Ten fixed frequency and two variable frequency receivers feed into a switching panel by means of which any or all the frequencies may be monitored and the beat frequency oscillators adjusted. Any selected signal may be transferred to a larger central speaker for easier copying of the message. This equipment is for communication with the National Network of Police Radio Stations.

The police complaint operators room (Figs. 4 and 6) adjoins the control room, with a glass partition between. A three-channel speech amplifier is used here to furnish police radio calls, music or instructions for general personnel, and paging information to ninety-six speakers in the building. Provisions have been made for eight complaint operators to receive emergency telephone calls for police services, and an electrically operated continuous belt delivers the written complaint sheets through the wall to the dispatchers' desks in the next soundproof room.

Positions are available for two regular dispatchers and a special dispatcher. (Fig. 7) The special dispatcher may take charge of a group of vehicles as might be necessary in emergencies. One regular dispatching position handles routine calls and the other position takes over when nearby files must be checked for such information as persons wanted or license registrations requested by the officers in the mobile units.

Voice operated disc recorders are used on the Police and Fire Department transmitters to record all incoming and outgoing messages. The dispatchers announce the time as calls are given, in order to establish the time of the call on the record; and the records are numbered and dated before filing.

Failures in the main station equipment have been infrequent, and mostly due to the great number of operation cycles it undergoes. Each 250-watt station cabinet incorporates a 50-watt auxiliary transmitter and spare receiver, which may be switched into service for use on the channel of the larger station while maintenance is performed on the regular equipment. Auxiliary power is available from an automatic starting 30 kva natural gas driven generator which also furnishes power for the exit lights in the building.

All operating consoles for the radio operators, complaint operators, and dispatchers, are of standard make unitized construction. Radio receivers and amplifiers are mounted in the lower part of the consoles on standard relay rack channels, and are accessible from the sides or front through clip-on panels. Wiring to the consoles is carried through ducts in the sub floor to centralized panels in the wall of the transmitter room.

A closed circuit television system is being installed throughout the building. (Fig. 8) It is composed of eight cameras and monitors working into standard television receivers through use of the small built-in oscillators of the monitors. A coaxial cable network put in while the building was under construction makes possible the distribution of the pictures to receivers in several key offices. (Fig. 9) The television was intended to assist the jail guards in preventing trouble between prisoners. Microphones will be located in places where disturbances may develop, and the accompanying camera activated only when the guards hear noises of a suspicious nature. One of the cameras is a portable unit which may be set up where needed, while the rest are mounted outside the jail walls viewing the interior through plastic panels. No attempt has been made to conceal them, in fact, their presence seems to be effective in preventing trouble between the prisoners, even though the camera may not be in operation. At present, the pictures of the cameras must be switched in the television control room when the person watching desires to see the output of a different camera. However, in the future, it is planned to make possible switching of the receivers by the viewer. It is also anticipated that a permanent record of important activity on

Fig. 5

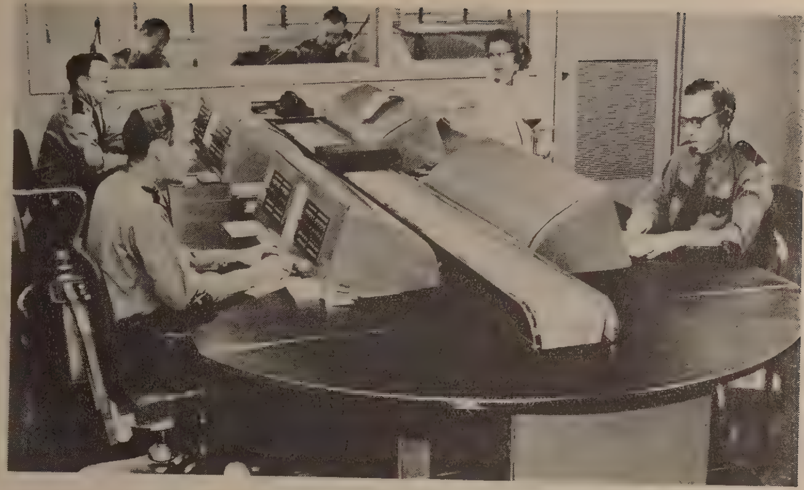

Fig. 6

Fig. 7

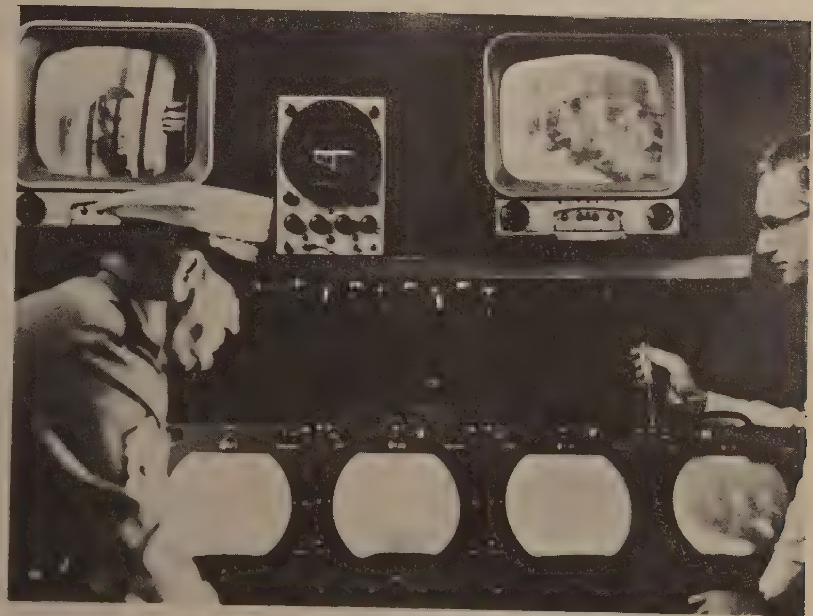

Fig. 8

Fig. 9

Fig. 10

Fig. 11

any of the monitor screens may be made by use of a moving picture camera. The sixteen millimeter camera will be installed on a track in front of the screens, at fixed focus and constant aperture, so that it may be moved to any one monitor and operated quickly.

In addition to the regular toll teletype machine, a building teletype system allows local communication between nine offices and several other police agencies including Galveston, Texas City, the County Sheriff Office and ties in with the Texas Department of Public Safety State Network.

To facilitate speedier communications, main offices in the building are connected to the communications operating room by a pneumatic tube system for rapid delivery of messages. An interoffice communicating system is incorporated between offices and outbuildings to relieve telephone congestion.

A separate, electrically shielded building near the base of the tower houses the Communications Division Repair Shops. There are four drive-in positions of sufficient size to hold large vehicles such as Fire Department trucks. Chain operated roll doors close the stalls when necessary. A flexible pipe for each vehicle allows connection to a suction fan for removal of exhaust gases. Radiant heat from hot water pipes in the concrete floor makes the outer working space comfortable in most conditions, even when the roll doors are open. Work benches are placed at each service area and small rolling tables with power connections make signal generators and test equipment accessible near the vehicle being worked upon. Five wood-topped work benches are in the outer section where vehicles are repaired and three in the inner air-conditioned section where units are taken for any lengthy repairs. All working positions have power and compressed air connections.

Most maintenance of mobile radios, except routine replacements of tubes and vibrators, is caused by the extreme heat of the trunk compartments and by the twenty-four hour service of the vehicles. The shops operate on a unit replacement system; that is, any mobile equipment requiring more than a few minutes to service is replaced by a reconditioned spare and the original set taken to the inner shop where a more complete repair is possible. Repair records are filed both by vehicle and radio serial number in separate files, because of the constant change of units from one car to another. A parts room with metal shelves and compartments which store approximately twelve thousand different parts connects with the inner shop.

Only one make of mobile equipment is in use at present, and a mock-up on the test bench holds a completely connected unit in a rotating frame so that it may be worked upon from any angle. A standard automotive-type quick-charger is used for six or twelve volt supply to the work bench. A pair of six volt wet batteries is floated across the output of the charger for better regulation, and a red signal light on the control panel indicates when the panel has been switched for twelve volt operation. A four frequency modulation and deviation meter is installed on an easily seen wall near the test benches. The center frequency, modulation and carrier level meters of this instrument have been duplicated with seven inch meters in the outer area of the shop to extend the usefulness of the meter. It has been found that a test antenna installed outside the shielded walls of the building receives nearly the same intensity of signal from a set on the test bench as from a set in a car in any of the stalls of the shop, making it unnecessary to constantly readjust the r. f. level of the master frequency and modulation meter.

Two communications trucks are in use by the Division for field maintenance and special assignments. (Fig. 10) The first, a panel delivery truck, is equipped with mobile units on the three frequencies, with a control panel and indicators which enable the driver to switch the microphone and the single antenna to any of the mobile sets. A rotating loudspeaker mounted on the truck roof is operated by a 50-watt amplifier with built-in electronic siren. A 110 volt supply is furnished by a transformer on the regular alternating current automotive generator. This truck is generally used for maintenance and construction away from the station, so a set of tools and spare radio parts is on hand for placement in it upon short notice.

The second truck is of large, van type construction with a winch and cable on the front. It serves as headquarters for emergency and disaster use and was equipped from ideas received from this department's experience at the Texas City disaster and similar, but smaller, emergencies. (Fig. 11) A working platform on top has mountings for a folding antenna mast and a battery of floodlights. A gasoline driven generator installed in the front supplies 110 volt AC to a distribution panel for the various outlets. Six and twelve volt DC is available for power to mobile units which are supplied with crystals for emergency operation on most of the public safety frequencies in this area. An electronically rotated loudspeaker can be used with a 50-watt power amplifier for the direction of workers or the control of crowds.

Personnel of the Division numbers fourteen, including eleven operator-repairmen, most of whom can act as main station operators or mobile repairmen, all working forty-hour-per-week shifts. All personnel of the Communications Division, except the secretary, come under the State Civil Service Law which provides for many benefits. Sick leave and vacation time is accrued each year and may be carried forward each year so that a month vacation is possible by skipping one year. Longevity pay is given after one year of service and longevity vacation days after fifteen years.

A COMMUNICATIONS CONSULTING ENGINEER'S NOTEBOOK

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Introduction

I have been asked to present this paper because of the interest of many of you in the work, experiences and outlook of a communications consulting engineer, a man who is engaged by a number of communications users, as contrasted to the engineer who is employed by one manufacturer or user.

A communications consulting engineer may be compared to an architect who by definition is one versed in the art of building, one who plans or designs and superintends construction, and one who advises and provides consultation on such matters. A communications consulting engineer, to be entirely objective in his work for the client, must be independent in his thinking, unbiased in his recommendations and should weigh carefully the various pros and cons of both the technical and human engineering problems and their solutions.

Most often, this engineer, in order to better his notebook of knowledge, and to be of more value to his client, associates himself with a group of fellow consulting engineers. Such a group should have experience in almost all phases of communications, including voice, video, telegraph, telemetering and remote control forms, employing both electronic and non-electronic facilities, such as wire, carrier, radio, television - with outside plant variations of poles, buildings, towers, standby power, etc.

As a member of such a group I should like to discuss some of the notes which I have made on experiences involving our various services and case histories.

Type of Service

These involve a wide variety of engineering services in communications to meet the requirements of many different industries and businesses. I am sure that all of us recognize that efficient communications are a valuable asset to any business. Well planned, fully adequate communication facilities combined with good operating practices promote close coordination and interlinking of administrative, sales, production and other functions, together with faster and more effective handling of inquiries and orders and the expediting of the flow of information in execution of activities. In short, efficient communications are important adjuncts to the achieving of better operating performance in modern business practice.

A communications consulting engineer, knowing that adequate, effective communications are always of vital concern to general business operations, has the following to say about some of his notes. He explains that a comprehensive study of the existing communications facilities and requirements including telephone, teletype, stock control, credit systems and the like, leading to plans for improvement and cost reduction methods, must be made before he can answer many of the questions put before him. This study will answer questions such as these:

How can telephone toll charges be reduced without restricting necessary oral communications?

When are directly connected circuits for telephone, telegraph or teletype, facsimile and video inter-communication economically advantageous?

Have the possibilities for savings and better service by the use of microwave radio been explored?

Are PBX operating expenses higher than they need be for efficient handling and routing of telephone calls?

To what extent has automatic distribution of telephone and recorded message traffic been applied?

How can recording devices save money and improve operations?

Following the answers to some of these questions, the communications consulting engineer may need to design and plan new communications for plants, offices, stores and warehouses including such considerations as:

Internal dial switching systems
Printing telegraph arrangements
Mobile radio telephone systems
Carrier derived transmission systems
Public address and paging systems

Remote control and indicating systems
Closed circuit television
Inter-plant and inter-office communications, using the most effective and economical means
Automatic stock control systems
Electronic credit checking and authorizing systems

A Case History

I have in mind the case history of a communications study we did for a large department store in New York and its various suburban branches in the same area. Briefly, the problem here for the communications consulting engineer was this: For the past 15 years or so this department store, in keeping with movement of the population to the suburban areas, extended its service and sales outlets by establishing branches of this store in the suburbs. However, the store had extended its communication service to the suburban stores in a rather haphazard way, without taking into consideration the specialized communication requirements and how they could be best met at the lowest cost.

To properly evaluate this situation, it was necessary for the communications consulting engineer to familiarize himself with the operations of the department store business. Merchandising, purchasing and ordering methods were studied, together with an analysis of the personnel concerned with these various activities in the main store and the suburban stores.

Following a technical and cost analysis of the telephone company facilities, both within and between the various stores, there evolved a number of recommendations to improve the efficiency of operations through better utilization of communications at lower costs. We found, for example, that many of the tie lines between the various stores were heavily overloaded yet there appeared to be a sufficient quantity of tie lines considering the traffic involved. After further study we found that many of the tie lines were installed on a one-way basis, i.e., dial out and ring in. A traffic count showed that most of the calls originated from a point where an operator was necessary to ring in. The recommendations called for immediate installation of 2-way dial lines with dial out and dial in service. The additional cost for this installation was nominal compared to the much higher utilization factor of 2-way tie lines. In another case there proved to be too many tie lines for the traffic load and grade of service required, and it was recommended that some of these be removed.

Problems of Right-of-way Companies

On other pages of the communications consulting engineer's notebook, you will find frequent comments on the popular subject of: "Should a right-of-way company such as a pipeline, a power or gas utility or a railroad lease its communications from a common carrier, or should it own and maintain its own communications facilities?" In his notes on this subject, he will have underscored words such as "economics", "reliability", "service" and "license responsibilities". He will also have underscored, "Diagnose this question separately for each company's operations. Be wary of making recommendations on the basis of quick comparisons and outside influences".

Pipeline companies, power companies, railroads, highways, toll roads, trucking firms, etc. are continually being subjected to pressure from both sides of this argument. It is the role of the communications consulting engineer to advise, in the interest of his client, that an independent and unbiased survey and study be made to determine the best and most economical means of providing the required communications, considering both leased and privately owned facilities and the various combinations of both.

I recall the case history of an interesting field physical survey and communications study which we did for one of the larger gas transmission companies. This company was faced with the immediate problem of improving both its vehicular and fixed telephone communications along some 300 to 400 miles of pipeline operations. Their heavy winter season was approaching and their existing communication system for maintenance and operations was highly inadequate. Up to this point it had relied upon ordinary long distance telephone toll service and localized mobile radio coverage by leasing common carrier units.

Although this type of communications meets many needs, it was far from suitable for the operations of this particular pipeline, and changes had to be made. Thereupon the management of this pipeline was confronted with a number of questions:

What type of communications will satisfy present requirements and also look forward to future requirements?

Considering the fixed telephone communications required and the telemetering and remote control needed, should microwave be planned to connect the VHF base stations and offices of the pipeline or should leased wire circuits be used?

Would it not be wise to have a combination VHF and microwave survey to locate sites and obtain options, all as a basis for making factual comparisons (economic and technical) to provide a plan for future growth, and to enable specifications to be prepared and bids to be received on a comparable basis.

After consultation with the pipelines management, the communications consulting engineer recommended that the best and most logical way to solve this problem would be to have an independent physical survey performed to locate both VHF base stations and microwave stations and to secure options for these sites. Following this physical survey in the field, a communications study was performed to determine annual operating costs for several different combinations of both leased and/or privately owned facilities.

One of the interesting results following this field survey and study was a 40% reduction in estimated annual operating costs for privately owned communications by reason of securing advantageous site locations for a combined VHF and microwave system.

<u>System Engineering and Construction</u>

I refer now to another section of my notebook, regarding the role of the communications consulting engineer in doing system engineering and construction coordination work. I would like to discuss more specifically the subject of microwave communication systems, which encompass many of the individual mobile and fixed systems in telephony, switching, telegraphy, facsimile, industrial control, indication, mobile radio, television, etc., with all their instrumentation, outside plant facilities and purposes.

Microwave communication systems require a considerable amount of planning systems engineering and specifications writing before construction and licensing can proceed and contracts be awarded. Because of the state of the art, much of this planning and system engineering has been done in the past by each manufacturer upon receipt of an inquiry from a potential user. Considering that each microwave equipment manufacturer has been doing this work on each inquiry, and considering that only one gets the sales contract, it has been necessary for each manufacturer to make allowances for high system engineering costs per contract concluded. For such reasons, the trend is in the direction of having the potential user, through his own qualified communications engineer, or through the outside help of a communications consulting engineer, do his own physical survey, economic study and specifications so that each manufacturer can furnish a final proposal bid at lesser expense, and reflect this in lower equipment bids.

Likewise, the potential user has been benefiting from this proceedure, since he does his planning and engineering, including physical survey, on the basis of evaluating any of the variety of commercial equipments with their RF and multiplex pro and cons. Oftentimes, advantages in favor of one or another type system will show in the results of field survey and frequency coordination analysis.

For reasons of frequency coordination, tower problems, site acquisition and the FCC construction permits, companies are finding it beneficial to follow this plan prior to deciding on make of equipment.

<u>The Role of Manufacturer</u>

Generally speaking, most manufacturers of microwave equipment do not care to be involved in the field construction work, involving installation of equipment and plant facilities such as towers, buildings, standby power, roads, fences, etc. Their reasons are several: that they need their engineers for development work, that the field work load is not even, that the overhead is necessarily increased in keeping qualified crews in readiness, and that the cost of administrating field construction using factory engineers is high.

Therefore there has been a trend for the manufacturers to be explicit in their equipment specifications and to supply sufficient installation instructions, together with requirements for towers, building, power, etc., to enable system construction and coordination by others qualified and experienced in this type of work.

In this connection the communications consulting engineer is being called upon to perform as the construction manager and coordinator and have available a construction staff. He is retained by the user to prepare contract specifications, to evaluate the various contractors' bids, to make recommendations, and to assist in the purchasing of supplies. He then supervises the contractor's work, and on completion conducts the acceptance tests - all of this work being done entirely in the sole interest of the user. The consulting engineer has the complete responsibility for the system performing as per the recommended and accepted system design and specifications. The manufacturers, in turn, assume responsibilities for performance of their products in accordance with their equipment specifications.

Conclusion

In summary, the communications consulting engineer must keep himself abreast of applications data, new developments and the statistical trends in each user industry regarding the economic, technical and other aspects of using open wire, cable, VHF, UHF and microwave systems. He also must keep himself aware of studies and pending decisions by regulatory bodies, together with policies and actions of the common carriers. ABOVE ALL, TO PROPERLY PERFORM HIS SERVICES, HE MUST MAINTAIN A REPUTATION FOR INTEGRITY AND UNBIASED THINKING.

THE OPERATIONAL FIXED MICROWAVE COUNCIL

Clifton D. Campbell
Chairman, Operational Fixed Microwave Council
And
Joseph E. Keller
Special Representative
Central Committee on Radio Facilities
of the
American Petroleum Institute
and the
National Petroleum Radio Frequency Coordinating Association

I. The Operational Fixed Microwave Council.[1] A Vehicle of Coordination and Co-operation.

The Operational Fixed Microwave Council,[2] which had been in the organizational stage for nearly two years, during which time intensive study and effort went into this important project, became a reality in Houston, Texas, on September 29, 1954, when delegates from various fields met to give their unanimous approval to new By-Laws which established the Council. The new Council, which during its developmental phases had been variously referred to as the Microwave Frequency Coordinating Association and the Microwave Users Council, is an inter-service agency established to guide the growth of microwave communications facilities through cooperative efforts among the Safety and Special Radio Services licensees entitled to use their higher frequencies. Attending the Houston meeting were 31 representatives and other interested parties from the aviation, petroleum, pipe line, forest products, forestry conservation, police, railroad, trucking, and power utility radio fields and equipment manufacturing companies.

One of the key functions of the new Operational Fixed Microwave Council will be the critically important job of advising and assisting the Federal Communications Commission in the drafting of rules to govern development of the microwave bands. Successful accomplishment of this job will be the means of forestalling and avoiding impending chaos in this field. The new Council, with the unlimited opportunities that it makes available to representative members, was acclaimed a means of salvation from the haphazard development of the microwave frequency bands among the various radio users. Creation of the new Council provides the convenient forum which is so greatly needed by the various organizations eligible to use the microwave frequencies for operational fixed communications needs, in order that technical information, mutual ideas, and common problems may be exchanged.

The objectives and purposes of the Operational Fixed Microwave Council, as stated by its By-Laws, are:

"(1) To foster the mutual interests of organizations concerned with the operation or use of operational fixed radio systems in the radio safety, industrial, land transportation, marine and aviation radio services;

"(2) To support and promote the allocation of microwave frequencies suitable and adequate for the use of such operational fixed radio systems;

"(3) To assist member organizations in formulating and coordinating views on uniform standards, fair and efficient regulations and technical developments beneficial to utilization of operational fixed radio systems;

"(4) To assemble data on microwave systems within the operational fixed radio service, maintain such information on a current basis, and furnish prospective users of such facilities with information on existing or proposed installations in a specified area; and

"(5) To concern itself with such other matters as may be incidental or implied in any of the foregoing specified objectives."

The Council By-Laws expressly provide that the operation, activities and actions of the Council are to be "voluntary and advisory", and that the organization is not to act in a representative capacity for the members of the Council individually. All information and data to be collected, compiled, and maintained by the Council will relate to operational fixed microwave stations, and will be available upon request to Council representatives, member organizations, and other concerns represented by Council representatives.

Comprising the Operational Fixed Microwave Council are organizations, or members of organizations, who are eligible to use operational fixed radio systems and who appoint accredited representatives to the Council. Representing the petroleum industry, for example, is a designated member of the American Petroleum Institute-National Petroleum Radio Frequency Coordinating Association; representing the power utility industry is a member of the National Committee for Utilities Radio; and representing the railroad industry is a member of the Association of American Railroads, to name a few of the organizations --each of whom, in this case, is one which helped spearhead the drive toward the establishment of the Council--who presently are members of the

Council. Each member organization is entitled to one voting member and a designated alternate.

Selected as Chairman for a period of two years was Mr. Clifton D. Campbell of Humble Pipe Line Company, who represents the American Petroleum Institute. Vice-Chairman L. E. Ludekens, of the Southern California Edison Company, and of the National Committee for Utilities Radio, and Secretary L. E. Kearney, representing the Association of American Railroads, will also serve two year periods as officers of the Operational Fixed Microwave Council.

Among those present at the Houston meeting from which emerged the Operational Fixed Microwave Council, was Colonel E. L. White, Chief of the Safety and Special Radio Services Bureau of the Federal Communications Commission, whose cooperative interest during the two year developmental period of the Council, had done so much to foster and encourage its growth. Colonel White spoke to the group regarding the future of microwave in the United States, touched upon many of the immediate problems affecting microwave users, and noted particularly the strong advisability of the early establishment of regular rules for microwave operations so that the developmental status of such facilities may be removed. It may be said that there emerged from the concerted action of the group to which he spoke, the vehicle which offers the best assurance for the early establishment of microwave rules.

In connection with those microwave rules, a preliminary report on the results of the survey of operational microwave was given by Dr. William M. Rust, Jr., Chairman of the API's Central Committee on Radio Facilities. Speaking of the survey of operational microwave, which he had been requested to make by the FCC, Dr. Rust said that indications are that microwave usage will more than double during the next five years.

II. The Background and Development of the Operational Fixed Microwave Council: The Enlarging Response to an Insistent Need

Probably a great many of the various groups interested in the microwave frequencies had been aware of the growing problem in this field, years before the Operational Fixed Microwave Council became a reality in Houston on September 29, 1954. Certainly, various groups within the petroleum industry were acutely aware of and were becoming increasingly concerned about the chaotic future which lay ahead for licensees in the microwave frequencies. Accordingly, at the June, 1952, Annual Meeting of the National Petroleum Radio Frequency Coordinating Association, the Chairman of that group appointed a committee to study the problem of microwave frequency coordination, and to report at the next meeting. Careful consideration and study of the problem prompted this committee to state, in June of 1953, that no successful plan of microwave frequency coordination could be administered effectively by NPRFCA alone, since microwave frequencies available to the petroleum industry are shared by all other users in the Industrial Radio Service. The committee therefore recommended, inasmuch as an effective coordination plan needed to be on an industry-wide basis, that other interested organizations such as the National Committee on Utilities Radio and the Association of American Railroads, be contacted with an eye toward forming such an industry-wide coordination council.

Members of the NPRFCA voted to contact all interested organizations relative to the eventual organization of a "Microwave Frequency Coordination Association", and in due time there emerged from the three organizations, NPRFCA, NCUR, and AAR, a tentative plan designed to provide the type of coordination which would enable all users in the Industrial Radio Service to participate. Not long thereafter, representatives of the three organizations met with members of the Commission's staff on an informal basis to discuss the feasibility of putting such a plan into action. FCC reaction to the idea was the encouraging expression that this would mutually benefit both the users and the Commission.

The Commission's blessing having been secured, a steering committee was set up consisting of Mr. C. D. Campbell of NPRFCA, Acting Chairman; L. E. Kearney, AAR; Dale Schreiner, NCUR; John McKinley, NCUR; and Joseph E. Keller, Special Representative of the Central Committee on Radio Facilities of the API. The steering committee's function was to contact all users in the Industrial Radio Service who had not already been contacted in order that they might be advised of the plan; to solicit and maintain interest and cooperation from all industrial radio users; and to lay the ground work for an organizational meeting which would bring together interested groups to discuss the common problem of microwave coordination and control.

During this same period of time, the Federal Communications Commission, recognizing the need for some degree of standardization in the microwave frequencies, issued a Notice of Proposed Rule Making in Docket No. 10500 on May 13, 1953, which would have amended its Rules regarding operational fixed stations operating on frequencies above 890 megacycles. Among the comments filed in this docket, were those of API's Central Committee on Radio Facilities, which recited the diligent work, study and concerted action which it had been undertaking in the microwave field, in cooperation with other principal user groups. An immediate need existed, the comments said, for a sufficiently high degree of standardization in these bands to permit the removal of the developmental classification, and this could be accomplished only through the adoption of a complete set of Microwave Service Rules, rather than the rule making proposed under Docket No. 10500, which contemplated Microwave Rules that set forth only minimum standards. The proposal in Docket No. 10500 was withdrawn by the Commission on October 29, 1953, on the ground that it appeared desirable to defer action until a complete set of Microwave Rules could be adopted.

While the plans for a coordinating council composed of various users in the Industrial Radio Service went forward, continuing studies were being conducted by individual groups. One such study resulted in the presentation of a paper before the AIEE Fall General Meeting in Kansas City, Missouri, on November 4, 1953, by Victor J. Nexon, Vice-President of Microwave Services, Inc. The paper, entitled "Industry Coordination of Microwave Communication Systems", reviewed the problems concerned with coordination of microwave systems in the various industrial services in order to obtain maximum utilization of the microwave spectrum. The paper cited the need for industry coordination regarding this critical problem, citing as reasons there for the already prevalent signs of interference, the lack of any coordination program set up to administer in the interest of all users, and the huge potential realizable through the use of microwave which has been frequently referred to as the "last frontier" of unused spectrum space. The summary conclusion of the paper was that coordination solutions on a beam-wide basis together with frequency and band width should be found to provide interference-free operation for a maximum number of microwave systems in the various areas. The single conclusion reached by the study on which this paper was based, as well as other individually conducted studies, all pointed to the need for an organization such as the Operational Fixed Microwave Council.

With the organizational meeting of industry groups interested in private microwave systems already in the offing, the FCC directed a letter on February 3, 1954, to the Central Committee on Radio Facilities of the American Petroleum Institute, and to the Radio Electronics Television Manufacturers Association, requesting that the Commission be furnished with information in connection with the drafting of proposed Microwave Rules and Standards. The job of assimilating and preparing the requested information and data is still being pursued by these two groups.

On February 24, 1954, the organizational meeting of the contemplated Microwave Council was held in Chicago. By this time, the name of the proposed organization had been changed from the Microwave Frequency Coordinating Association to the Microwave Users Council. Representatives of many of the industry groups utilizing the microwave frequencies in the Industrial Radio Service were in attendance. Chief of the Safety and Special Radio Services Bureau of the FCC, Colonel Ed White, was on hand to assure the group of the Commission's continued interest in the formation of the proposed Council, and to reiterate the need for a policy in the handling of microwave frequencies. Acting Chairman C. D. Campbell outlined the proposed plan and stipulated some of the factors that have to be taken into consideration when selecting frequencies for a new microwave system. Some such factors, he said, are:

1. The geographical separation from existing systems on the same frequency;
2. Antenna patterns, major and minor lobes, size and shape of reflectors, etc.;
3. Microwave tower stability: How much twist due to wind could be tolerated without interference to other stations.
4. Any plan to be effective would have to be on an industry-wide basis since microwave frequencies are allocated on a shared basis to nearly all radio services under the Safety and Special Radio Bureau of the FCC.

A draft of proposed By-Laws for the Council was presented by the Special Representative of API. The proposed By-Laws, which set forth substantially the same purposes and provisions contained in the By-Laws which were eventually adopted at the Fall meeting of 1954 in Houston, were discussed and tentatively adopted, subject to final approval at the forthcoming meeting in September of 1954. The proposed rule making under Dockets Nos. 10500, 10797 and 10821 relative to proposed standards and rules which would affect the microwave services, were discussed; Messrs. Campbell, Ludekens, and Kearney, who had originally been chosen as acting officials for the proposed Microwave Users Council, were formally nominated and elected to fill their posts as Chairman, Vice-Chairman and Secretary, respectively.

The successfully conducted organizational meeting established and unified a purposeful nucleus of industry groups. During the months following the organizational meeting in February, the By-Laws of the tentatively established Microwave Users Council were circulated and subjected to further review and study by the various groups. A special meeting was held on June 11, 1954, in order to review and consider certain additions to the By-Laws which had been filed by one of the representative groups. At this special meeting a subcommittee was appointed which was to receive all comments or suggested changes to the By-Laws and to prepare a re-draft of the By-Laws for presentation to the entire membership of the Council at the forthcoming September meeting. These proposed amendments were accordingly submitted to the entire membership of the Council meeting at Houston, and unanimously approved, to finally establish the Council under its new name of Operational Fixed Microwave Council.

Official approval of the By-Laws of the Council has already been given by the American Association of State Highway Officials, the Association of American Railroads Communications Section, the Committee on Manufacturers Radio Use, the Forestry Conservation Communications Association, National Bus Communications, National Committee on Utilities Radio, National Forest Industries Communications, the American Petroleum Institute's Central Committee on Radio Facilities, National Petroleum Radio Frequency Coordinating Association, the Special Industrial Radio Service Association, and the American Trucking Association. Tentative executive approval has come from the Associated Police Communications Officials, Inc. It is expected that the American Waterways Operators, who

has the matter under consideration, will officially approve the By-Laws and formally enter the Council in the very near future.

Inasmuch as a majority of the members present at the organizational meeting have already approved the By-Laws, the Operational Fixed Microwave Council is presently duly constituted to proceed with its objectives as a full-fledged organization and plans are progressing toward the establishment of a microwave informational exchange service whereby microwave users would report all of the vital data concerning their systems so that it might be plotted on Council maps. It is the sincere feeling of all of the members of the Operational Fixed Microwave Council, and unofficially also the feeling of the Commission, that the establishment of this Council represents a most significant and constructive step toward the successful plotting and efficient utilization of that "last frontier" of unused spectrum space--the microwave frequencies.

Prospective microwave users are invited to consult with the Council on their frequency problems so that interference may be avoided and so that the most efficient use may be made of available spectrum space. The Council organization represents the first successful effort to deal with mutual frequency problems at the inter-service levels. The Council provides a badly needed forum to coordinate the use of microwave frequencies, to serve as a means of coordinated expression of viewpoint to the Commission on microwave matters, to provide the Commission with the factual data it will need to adopt permanent rules for a microwave service and to eliminate the developmental status of the service which exists at this time.

The Council has a challenging future indeed. Microwave installations make a vastly important contribution to the efficient operation of the American industrial plant in time of peace. These microwave installations will serve in an even more important capacity in the event of another national emergency. The work of the Council is so important that it merits the cooperation and support of all industrial radio users. The progress made to date has been most gratifying. It foreshadows the even greater accomplishments which lie ahead.

References

[1] Operational fixed station - A fixed station, not open to public correspondence, operated by and for the sole use of those agencies operating their own radio communication facilities in the Public Safety, Industrial, Land Transportation, Marine or Aviation Service.

[2] This article is based on informal remarks made at the national meeting of the Professional Group on Vehicular Communications of the Institute of Radio Engineers by Mr. Campbell and Mr. Keller and has been prepared for the official minutes of this meeting and for the use of the various user groups in assuring a wider understanding of the purposes of the Council and its current operation.

MOBILE RADIO CHANGES THE PACE OF THE NATION

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Summary--The purpose of this paper is to direct attention to the many uses of radio communication systems, some of them unusual and seldom heard of, and to show how organizations, through the use of radio, are better able to coordinate their activities and thus provide a quicker and more efficient service to the public.

INTRODUCTION

The theme which has been selected for the Fifth Annual Meeting: "The Role of the Communications Engineer in American Industry" is one which should appeal to all of us. I consider it a very good topic and a wise choice because I believe that it is time for us to pause a few moments and review the work that has been done by this hard working group of individuals and show how the systems that they have designed and installed are contributing to the American way of life.

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For the past 25 years or so we have heard about the very satisfactory results that the police departments have obtained through the use of two-way radio. At the present time the police department in every state in the union relies upon radio for a large percentage of its communication requirements. All of the large cities and many small towns and villages also have their own radio communication systems and cooperate with the state police in their day-to-day operations. The use of these well organized radio communication networks has had a marked effect in the reduction of crime. Police radio systems are not used exclusively for the apprehension of criminals, however. One of the more recent developments is in the regulation of automobile traffic along the turnpikes - those high speed toll roads that are springing up all over the country. The successful operation of a modern turnpike would not be possible without adequate communication. Provision must be made so that when necessary the personnel of the entire system can be alerted to receive special instructions or warnings of adverse weather conditions that might result in hazardous driving conditions. Communication requirements vary from minute-to-minute and hour-to-hour. Some communications must be broadcast system-wide while others may be of interest to a particular section only, or to the officers at one of the interchanges, or to a single patrol car on the highway. Provision must be made for the exchange of information between any of these communication points. These complex communication problems have presented a real challenge to the engineers but they are being solved. Mobile relay stations operating in conjunction with fixed relay, base, and mobile stations, provide a very complete as well as a very flexible communication system. Such integrated communication systems are also used extensively by other organizations which have similar communication requirements. One phase of the flexibility and usefulness of the turnpike radio system can be demonstrated by the following example. In case of an accident on the highway the wrecker is promptly dispatched to the scene and the road cleared so that traffic can move in a normal manner. If ambulances are needed they too are dispatched and aid rendered to the injured. If hospitalization is necessary the extent of the injuries is made known to the nearest hospital, while the ambulance is enroute, and suitable arrangements for receiving and treating the patient, thereby, are made in advance. In serious accident cases, the few minutes saved may mean the difference between life and death. The coordinated effort of various groups of employees working together results in quicker and more efficient service to the public.

Doctors and veterinarians, whose practices are in remote areas, have found radiocommunication systems to be very beneficial in many ways. By being able to keep in close contact with his home or office, the doctor can proceed with his routine calls and yet he can be reached if an emergency call is received. In some instances several rural doctors have combined their practices and installed a common radiocommunication system. Cooperative arrangements such as this often result in better medical service for both people and livestock and allow the doctors more freedom in arranging their daily schedules and save many miles of travel.

In the larger cities the doctors, as well as other persons engaged in outside work, can subscribe to a two-way radio communication service which is provided by the local telephone company, or other communications common carrier. Some companies offer a one way paging service. In the latter service two methods of operation are commonly used. In one, the subscriber carries a small battery operated fixed-tuned receiver on his person and at designated times he turns it on and listens for his name or his number to be called. If he is being paged he must call the operator at the base station over the land line telephone in order to get the complete message. In the other method, a special receiver which responds only to a particular coded signal is installed in the subscriber's car. The receiver is left in continuous operating condition during the time calls are expected. If a call is received a metal flag pops up and remains in position until manually

reset. The purpose of the visible signal, of course, is to indicate to the subscriber that a call has been received. He then calls his office or home in accordance with some pre-arranged plan.

Fire departments have used radio communication systems for many years for dispatching fire-fighting equipment to the scene of the fire. By being able to keep in constant communication with the fire house and central headquarters of the fire department, the fire chief may dispatch fewer pieces of equipment and fewer men on the first alarm and then send additional help later if needed. Thus, ladder trucks and other special equipment may be kept in reserve to be used where it is needed most. The first firemen to reach the blaze report back to headquarters as to the seriousness of the fire. If it appears that the fire can be brought under control quickly, fire trucks that may have been sent from neighboring districts are called back so as to give maximum protection in their own vicinity. If all equipment is at the scene of the first fire when a second fire is reported, some of the equipment can be dispatched to the second fire immediately without returning to the fire house. It has been reported that one fire department answered seven alarms before returning to the fire house. Small easily carried transmitter/receiver units, commonly called "walkie-talkie" sets are used to great advantage at the scene of the fire. Firemen carry these units into a burning building with them and receive instructions from the fire chief as to how to proceed to the source of the blaze and bring it under control. In directing the operation of the crew, the fire chief can warn them of impending danger such as collapsing walls and roofs and he sends aid quickly if a fireman is injured. Firemen are able to keep the fire chief advised of the progress being made and to call for additional help if needed. Although it is desirable for the fire departments in different districts to use separate frequencies for dispatching purposes, an attempt is usually made to have all portable equipment in a particular area operate on a common frequency so that the various departments can work together when necessary.

The use of radio in the protection of forest lands is gaining in importance. Transmitters and receivers are installed at the various lookout stations and fire fighters are dispatched as soon as fires are detected. In recent years, men and equipment have been carried into the area by helicopter or airplane and parachuted to the ground a safe distance from the blaze. The fire fighters then proceed the rest of the way on foot. By being able to communicate with an observer in the air or in the lookout tower they can be kept advised of the direction and the rate the fire is progressing and thus can prevent themselves from being entrapped in an area where escape is difficult or impossible. Radio communication permits widely separated groups of fire fighters to coordinate their activities. Men and equipment are shifted around into positions where the need is greatest.

Major airlines depend very heavily upon radio for communication -- not only for safety purposes but also for flight dispatching and other operational communications. Radio communication equipment is installed in ambulances and other emergency vehicles for ground traffic control at airports. It is used by baggage handlers at the baggage transfer point, by the ramp parking coordinator, and the maintenance crews. Owners of aircraft used for business and pleasure rely upon radio for communication with the airport control towers and airways enroute stations.

Motion picture companies have found radio communication almost indispensable to their operations. While shooting scenes inside the studio, actors and actresses often have a small receiver concealed in their clothing through which they receive cues and instructions. When shooting out-of-door scenes radio communication plays an important part in coordinating the action of widely separated groups in timing their appearance before the camera with split-second precision. In those scenes in which the radio transmitting and receiving equipment is used, but must be kept out of sight, it has been cleverly concealed in wagons, in dummy packing crates, on horses, behind bushes, and many other places.

Nearly every electric power and light company and gas company in the country uses radio communication in connection with its day-to-day operations. In many instances the messages are of an emergency nature and concern the dispatching of service trucks to repair transmission lines that have been damaged by fire, storm, flood, or other accident, or to restore service that has been interrupted for some other reason. Routine messages are transmitted to coordinate such construction activities as cable laying, wire stringing, and pipe laying.

Radio communication is used by the petroleum industry in every phase of the operation — from the location of the oil deposits to the transportation of the finished product. The oil fields are usually located in remote areas where regular wire line telephone service is impractical to install. Nevertheless, reliable communication is required in order to keep the personnel at the field headquarters office in contact with the travelling field supervisor and the crew at the well site. Well drilling is a hazardous occupation. Fires, explosions, and accidents occur quite frequently and the services of medical and fire-fighting personnel may be required at any time of the day or night. Similarly, the services of the many specialized well service companies may be required on very short notice if a well is to be saved. Mobile radio communication systems are used by the truckers who transport the heavy well drilling equipment, by the roving pipeline repair

crews, and by the men who patrol and inspect the transmission lines from the air. Although it is difficult to state any specific amount, it stands to reason that the savings that are realized by the more efficient operation ultimately are passed on to the consumer in the form of lower prices for gasoline, oil, and other petroleum products.

In shipyards radio communication is being used by the construction, maintenance and repair crews, by crane operators, and by foremen. It is used extensively by tug boat operators and has been found to be exceptionally helpful in docking operations. Docking a large ship is a delicate operation and one that must be performed with care and precision and often under adverse weather conditions. If we go back to our school days for a few moments we remember the physics prof telling us that mass times velocity equals momentum. This fact can be clearly demonstrated if one will stand by during mooring operations and feel the impact as a large ship strikes the dock. The ship, while moving very slowly, exerts a tremendous force against the dock because of the great weight, and damage to the ship or the dock is always a threat. Without the use of radio, the tug captains rely upon whistle or visual signals for instructions. These signals merely tell the captain to go or to stop and there is a considerable time lag between the time an instruction is given and the time in which it is carried out. When the tug is on the side of the ship away from the dock the captain cannot see the distance between the two and the tugs must move very slowly so that the movements of the ship will be kept under control. With the use of radio communication equipment, the tug can move much more efficiently as detailed instructions can be given, all activity is coordinated, and every one knows at all times the relative position of the tugs, the ship, and the dock. Radio communication between the ship, the tug-office, and the tug, also adds considerably to the convenience of the operators when a ship is coming into port because arrangements for a tug can be made while the ship is still at sea. If a tug is not available at the proper time the ship captain is so advised and does not bring the ship in until he is assured that a tug will be on hand. Radio communication also permits the operators at the tug office to schedule the operation of their tugs so that there is less wasted time.

Radio communication systems are also playing an important role in the preparation of canned and frozen food. Take, for example, a food processing plant in an area surrounded by farms. The plant depends upon the farms for produce, and the farms depend upon the plant for a market place in which to sell their crops. Close coordination between the two is required -- particularly at harvest time. After harvesting, the food is sent to the plant where it is first graded as to size and quality under the supervision of State and Federal Government inspectors. If the crop has been harvested too soon and is still immature the quality may be affected. Under such conditions the farmer does not receive full price for his produce. On the other hand, if it is over-mature it may not be usable at all. While harvesting on a 24 hour a day basis, harvesting rates must be changed several times during the day. If the condition of the produce can be improved in any way the farmer should be notified as quickly as possible. During harvest seasons the farmer is usually in the field where it is difficult to communicate with him. Usually he can be reached by radio. Under such circumstances, he may be told by the crop supervisor to wait until the crop is more mature before sending it to the plant. Or he may be advised that the crop is not usable in which case he will spare himself the time and the expense of sending a shipment that cannot be used. Without the use of adequate communication, difficulties are encountered in having the food shipped to the plant in quantities that can be used. As crops in the same general area mature at or about the same time there is a tendency for all farmers in the area to start shipping at the same time. If too much produce is received the processing lines are overburdened and the food spoils during the waiting period. Some foods are so perishable that they will spoil within four hours after harvesting. If the farmers delay the harvesting too long the food may spoil in the fields. If shipments are irregular or too small work schedules at the plant are disrupted.

The use of radio for communication between the processing plant, the supervisors, and the trucks in the field, provides the close coordination that is required. Shipments may be regulated so that the food arrives at the processing plant in the best possible condition and in quantities that can be handled. This results in improved food quality for the consumer, a dependable market and top prices for the farmer's produce, more productive time for the plant, and steady employment for the workers.

In the transportation industry each passing day sees the use of radio communication systems more widespread. In many cases the results obtained through the use of radio have actually exceeded the expectations of the user. For many years, taxicab operators felt that a radio system would permit more rapid dispatching of the cabs and reduce "dead mileage" because the cabs would not be required to return to a call box or some other designated place after a call has been completed. Soon after World War II a few brave souls ventured into the unknown and installed experimental radio systems. It soon became evident that they were correct in their prediction because after the system had been in operation a short time it was found that the cabs were being dispatched more rapidly and dead mileage was being reduced. Some operators claimed that four radio equipped cabs could do the work of five cabs without radio. Others claimed even greater improvements. It was also found that a high percentage of "lost busi-

ness" was being recovered. Lost business is a condition which is brought about by the inability of the dispatcher to get a cab to a prospective customer within the time in which the said customer is willing to wait. Some people are more impatient than others, of course. It has been said that the patient ones are those who will wait ten minutes. An increase in new business was noted also because, as service improved, more people began to rely upon the taxicab as a means of transportation.

Radio communication has also found a place in the operation of the large inter-city buses. One of the most exasperating problems for the bus operators to solve is that of having the right number of buses at the right place at the right time. People's travelling habits are rather unpredictable and it often happens that a large group will arrive at a bus station and expect transportation at a time when only one bus has been scheduled for the trip, or conversely, a large crowd is expected and several buses provided but only a few people decide to ride the bus on that day. Holiday traffic is particularly difficult to estimate; but, with a radio system the dispatcher can be in constant communication with the drivers on the buses as well as with the ticket sellers at the terminals along the way, and he can be kept advised as to the number of passengers on each bus and the number of passengers waiting at each stop. If extra buses are needed, they often can be dispatched in time to meet the schedule and the passengers accept the additional facilities as a matter of course and without realizing the planning and coordination that was required to provide the extra service.

Operating conditions are somewhat different in an urban transit system. There seems to be no benefit in equipping the street cars and buses used in a city transportation system with radio because these vehicles operate over much shorter routes and any unusual traffic conditions are quickly noted. Therefore, the radio communication equipment is usually installed in the street supervisors' cars and in the maintenance vehicles. Reports of any difficulties are given to the dispatcher and then relayed to the supervisor in the area of the trouble. He takes steps to restore the service to normal as quickly as possible. If a street car or bus is involved in an accident he can advise the dispatcher as to what equipment is needed to make the necessary repairs or remove the vehicle from service. Close coordination with the local police and fire departments is often very necessary and is made possible through the use of the radio system.

Radio is finding a well earned place for itself in connection with the operation of railroads. Many hours of time and many miles of walking are saved every day thru its use. Freight trains are made up in the railroad classification yards but before a train pulls out each car must be checked carefully to see that all cars that are scheduled to be in the train are actually there and that there are no extra cars. Before the use of radio was employed in this operation, a car checker would walk along the track and write down the number of each car in the train as he passed it. This work was particularly difficult in stormy weather. Then after he had finished, he walked back to the yard office and checked his list against the official list. If the two lists did not agree exactly -- say, for example, in his list two digits of the number for one of the cars were transposed-- then he went back until he found the car in question and verified the number. If the wrong car was in the train it had to be replaced. But if he had made a mistake in copying the number -- and the right car was in the train -- then the time spent in this checking operation was not very productive. This job can be done much quicker and easier with radio. The car checker straps a walkie-talkie unit on his back and as he walks along the track he reads off the car numbers into the microphone and at the same time the attendant in the yard office checks the official list of cars and numbers. If a discrepancy is noted the attendant interrupts the car checker immediately and they work together in determining its cause. Radio communication equipment is also used extensively on switch engines for speeding up switching operations. Many trains are now running on very tight schedules and when there is a break-down of equipment, repairs must be made quickly. Here is one example of how the use of radio prevented what may have been a serious accident and at the same time saved an appreciable amount of operating time. As a freight train passed a wayside station, an employee noticed that one of the tank cars had a "hot box" and was on fire. A hot box is caused by insufficient lubrication of the axle bearings and if not corrected may result in a frozen bearing which could lead to derailment of the car. A fire on a tank car is particularly dangerous because there is always possibility of an explosion. The employee recognized the seriousness of the difficulty and called the conductor on the train, by radio, and told him of the trouble. The train was stopped and, while the fire was being extinguished, he contacted the engineer on a switch engine to follow the train to the next turnout and remove the defective car. When the train started again it proceeded slowly and by the time it reached the turnout the switch engine had caught up and the defective car was set out on the siding. The entire incident caused only a few minutes delay.

Radio communication equipment is installed on vehicles used in connection with the maintenance of buildings and grounds at the large universities, in orchards, and cemeteries, on ranches, golf courses, and hunting clubs; it is installed on lift trucks used for materials handling in warehouses, factories, and refineries; it is used by a few drive-in restaurants for relaying orders from the car-hops to the kitchen; used by detec-

tive agencies in the protection of life and property; it is used in the construction and maintenance of telephone lines; it is used by radio consulting engineers when adjusting the radiation pattern of a directional antenna array; it is used by plants operating induction heaters while measuring the extraneous radiation field.

Its use has also invaded the advertising business. No longer is it necessary for a skywriter in a single airplane to slowly trace out his message in the sky. Instead, seven planes fly at uniform speed in straight line formation -- one alongside the other. Block letters are made by releasing puffs of dense white smoke from one or more planes at proper intervals. The letter "I", for example, is made by releasing a puff of smoke from each plane at the same time. The valves in the smoke chambers are controlled by coded signals which are transmitted by radio from the command plane, usually the center one of the seven. A separate signal automatically controls the valve in each plane.

Improvements in the design and construction of radio communication equipment are being made constantly. Transmitters and receivers are made smaller, lighter, more reliable, and more efficient. Simultaneously, more people are learning that their communication problems can be solved through the use of radio, in fact, the list gets longer every day. Mobile radio communication is considered by many to be a tool of industry. If this is true, then it is the responsibility of the communications engineer to provide a tool that will work. In my opinion, the most important role of the communications engineer in American industry is that of designing a radio communication system that will assist in coordination the activities of an organization and thereby reduce the non-productive time to a minimum. From the foregoing, it is evident that he has established an enviable record. It is not possible to follow the trail of events in the history of radio "from galena to germanium" without coming in contact with the work of the communications engineer at every turn of the road.

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RADIO EQUIPMENT WHICH MEETS THE CHALLENGE OF 6 AND 12 VOLT VEHICLES

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I. Introduction

The theme of the Fifth Annual Meeting of the Professional Group on Vehicular Communications, that is, "The Communication Engineers' Role in American Industry" is, I believe, most apropos.

The challenging tasks brought about by the ever changing and increasing operational requirements of communications equipment, the tighten- of specifications due to increased VHF channel utilization, must be anticipated and promptly resolved in order to maintain a position of prominence and integrity in a growing competitive industry.

The subject which I have chosen today is a typical example of the engineers' role in industry, namely solving the communication equipment problems brought about by the introduction of the 12 volt electrical system in the automobile industry.

II. Need For a 6/12 Volt System

The problem originated in 1953 when the first mass produced automobile with a 12 volt electrical system was introduced. True, there were numerous other trucks and vehicles with 12 volt systems already in existence but none were in such mass quantities as to cause an interchangeability problem in radio equipped fleets. Upon first hearing of the proposed change to 12 volts, it was apparent that we had a laborious task ahead of us. It was imperative that we move with the utmost speed to be prepared to meet the problems and inquiries which we visualized arriving from the customers in bushel basket loads. Even so, the problem was not as simple as it appeared to be on the surface.

To supply the field with information and parts necessary to convert existing 6 volt equipment to 12 volts was not sufficient, for some customers would need to retain interchangeability in order to maintain an economic system. This would not be possible if half the equipment was 6 volts and half 12 volts. Also, any new equipment would not only have to be capable of operation from 6 and 12 volt systems but also would have to be capable of working with any of its 6 or 12 volt predecessors. As far as the customers were concerned, this was a must.

In order to determine if we had our sights properly aimed, we attempted to ascertain from the various automobile manufacturers what the future picture was with respect to 6 and 12 volt systems. Unfortunately we had hit upon a top secret question. They were absolutely non-committal. It was impossible to establish whether or not any trend was going to be created by the new 12 volt automobile. To insure ourselves against possible future problems, and to fully protect our customers against obsolescence, it was obvious that our new equipment was going to have to be completely inter-changeable, without modification, between 6 and 12 volt vehicles.

Since the early days of this problem, our efforts have been shown to be well justified, for at the present time, five different standard makes of automobiles are equipped with 12 volt systems. Next year the new system will make its appearance in several more brands, including the so-called low price three, and indications are that an additional number will join in the following year.

III. Philosophy of Approach

Once we had established the basic requirements of our new "6/12" equipment, it was necessary to adopt some philosophy as to the manner in which the end result was going to be achieved.

To protect the equipment against unnecessary dangers because of human error, it appeared desirable to have no internal jumper or component changes required when moving a set from vehicle to vehicle. The requirements of emergency fleets such as police and fire departments, further precluded the use of internal changes. Since the 6/12 feature was not required by all customers, it had to be accomplished at a minimum extra cost, which further meant that a minimum of extra parts and components could be used. As drain was also of primary importance, no waste of power could be tolerated.

With these goals in mind, some months were spent on the project before a scheme was devised, which necessitated the use of a vibrator consisting of two independent interrupters within a single envelope, but driven by a common driving coil. We referred to it as a "split-reed" vibrator. We then had to call upon the vibrator manufacturers to develop such a device. This

basic vibrator was not new but a suitable vibrator had never been developed for an application such as ours. This, of course, meant months of development. The first completely interchangeable 6/12 volt set was delivered early in 1953. It could be moved from a 6 volt car to a 12 volt car or from a 12 volt car to a 6 volt car without any changes to the equipment. Original installation required that the 6 volt car have a 6 volt cable and the 12 volt car have a 12 volt cable, but this was no problem since once the cable kit was installed in the vehicle, it usually became a permanent fixture. The radio sets could then be freely switched around as necessitated by maintenance, vehicle breakdowns, and the like. Current cable kits are designed to be interchangeable between 6 and 12 volts.

The basic circuit of the new 6/12 volt unit consists of a power transformer with two separate 6 volt vibrator primary windings. Each winding has its own independent reed, but the two reeds are ganged together so that they are always operated in synchronism. This arrangement permits operating the windings either in series or in parallel as required. The proper connections are determined in the primary power plug (Fig. 1). Assume that the vibrator reed in Fig. 1 is in the upper position. With a 6 volt primary source as shown, the instantaneous input currents will be in the directions indicated by the solid arrows. Separate currents will be fed from the battery to the two primary windings, but each will be in phase, aiding. The same action will take place when the reed is in the lower position, but the currents will be through the lower halves of the windings in the reverse direction. The filaments, relays, and other 6 volt elements are connected in a series-parallel, 6/12 volt arrangement with a common bus in the center. When operating from 6 volts, the two outer buses are grounded and the center bus is fed directly from the battery. Note that the lower bus is permanently grounded but the top bus is grounded in the power plug.

When a 12 volt cable is connected to the systems, the upper and lower primary windings are placed in series by the jumper across pins 2 and 3 in the power plug. If the reed is again in the upper position, the primary current will now be in the direction indicated by the dashed arrows. The current is still, however, in the same direction through each winding, that is, in phase, aiding. Also, since the 12 volts input is divided equally across halves of both the upper and lower windings, each half will still be operating from 6 volts and the same number of ampere-turns will exist, producing the same secondary voltage. The 12 volt input is also connected to the top bus of the filament and relay arrangement supplying power to all the 6 volt elements. The center bus is connected to the center junction of the two transformer primary windings. This connection offers a very distinct advantage. With the windings connected in series, the unit acts as an autotransformer in much the same manner as a 12 to 6 volt converter, producing 6 volts at this junction. It is therefore not necessary to have a balance between the 6 and 12 volt sides of the filament arrangement. Any unbalance current will be supplied by the autotransformer action of the primary windings. This means that power wasting voltage dropping resistors are no longer needed in series with the odd tubes and relays. Furthermore, tube life and reliability is increased as the heater voltages remain balanced under all conditions of operation. Note also that the vibrator driving coil is connected between this junction and ground. Since this bus is always at 6 volts, it is possible to use a 6 volt vibrator for either 6 or 12 volt operation.

Another inherent and desirable feature of the system is that the two vibrator halves share the heavier current load on 6 volts, while on 12 volts, which is more difficult to commutate because of arcing problems, the contacts form a double break circuit, thereby affording longer vibrator life for either application. With this new equipment, vibrator life upwards of 5000 hours may be realized.

For higher powered transmitter application where one vibrator would be inadequate, two vibrators and transformers are used. Each vibrator operates independently of the other with its own transformer, and the higher output voltage is obtained by adding the two rectified output voltages from each transformer circuit.

One of the more fascinating aspects of the system is that the 6/12 volt feature has been accomplished with practically no addition in cost.

This new 6/12 equipment has now been in mass production and in the field over a year and a half, and has been accepted with much enthusiasm.

Recently we had the pleasure of announcing a new addition to our 6/12 volt line of equipment - a 6/12 volt dynamotor power supply. Connections and intercabling to this unit are identical to that of the vibrator power supply and the two are completely interchangeable.

One of the features of the dynamotor power supply is a dual output dynamotor - a high voltage output for the final amplifier stage and a lower voltage output for the remaining transmitter stages. This eliminates the need of large power wasting resistors and makes it possible to have a 60 watt transmitter with less than 50 amps battery drain.

Unfortunately, the development of the new "6/12" line did not bring us to the end of our problems for in addition to producing the new equipment it was also necessary to provide a solution for the customer who already had 6 volt radio sets and was replacing some of his older vehicles with 12 volt cars. What was he going to do with

his radio equipment? For the individual who had only one or two radio equipped automobiles to be concerned with, it appeared the simplest and most economical solution was to actually rewire his equipment for 12 volt operation.

To assist the customer with such modifications, we provided field conversion instructions and parts. In many cases this field modification was quite simple and required but a few resistors and capacitors, as major items such as transformers were already designed for 12 volt operation.

For larger operations involving fleets of radio equipped vehicles, rewiring was not a practical solution, for here interchangeability between the different vehicles of the fleet was desirable. In answer to this problem we developed a 12 to 6 volt converter. (Fig. 2)

This was a compact, highly efficient unit which could be mounted alongside the radio set and would permit the fleet operator to use standard 6 volt radio equipment throughout his mixed fleet of 6 and 12 volt cars. Thus the interchangeability and flexibility required in larger systems is retained. The necessity of extra spare or "emergency" units is eliminated. To assist the customer who proposes to expand his fleet or radio system, cable adapter kits have been made available which permit him to use new 6/12 volt equipment interchangeably with his old 6 or 12 volt equipment.

So, summarizing briefly, we find the new 12 volt systems should really be no serious cause for alarm. Whether you are using older equipment, buying new equipment or mixing fleets, there is an engineered solution for every mobile radio installation or modification. The owner of advance designed equipment is protected against obsolescence. This is a part of the communication engineer's role in American Industry.

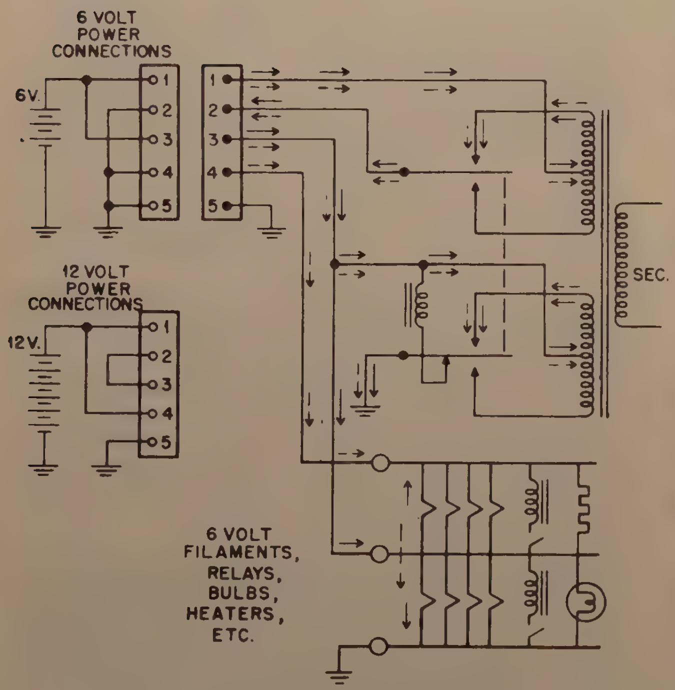

Fig. 1 - The 6/12 volt system.

Fig. 2 - The 12 to 6 volt converter.

DESIGN, INSTALLATION AND MAINTENANCE OF 1,000 UNIT BASE-MOBILE SYSTEM

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At our banquet last night, Mr. W. D. Owsley of the Halliburton Oil Well Cementing Company addressed us on the subject, "The Importance of Fast Communications in the Petroleum Services". He discussed, from the management's viewpoint, the very large radio system operated by the Halliburton Company--comprising approximately 100 stations and 1,200 mobile units. The company I represent, Communications Engineering Company, was privileged to install and is now maintaining approximately 90 of these stations and 1,100 of the mobile units.

Because it is a widespread system, extending from the Canadian Border to the Gulf of Mexico, from Michigan to California, the problems encountered in its design, installation and maintenance may be representative of others in a similar service. While in general the technical installation and operation of this system is routine, I would like to describe a few features which may be of interest.

When I was first invited to deliver this paper, one of your Committee suggested the title be "Ten Problems and Ten Solutions". It was flattering to say that we had as many solutions as we had problems! I can assure you there were far more than ten problems and, furthermore, we do not yet have all the solutions.

A BIG PARTY LINE

A single base-mobile frequency--49.74 mc--is used throughout the Halliburton system. As you can imagine, this is quite a party line! All transmitters are adjusted for a maximum deviation of plus or minus 6 kc and all receivers are of the narrow band 20 kc type. When the present 40 kc channels are halved, no modification or adjustments will be required. All mobile transmitters and 64 of the base stations have 60 watt output and the remaining 42 base stations have 250 watt output.

The most important consideration in the design of any oil field system is to determine first the operational requirements. This may sound academic but it is absolutely necessary that the information be obtained <u>in the field</u> at the Division or District offices. The main office may have a general idea of the area of operations but quite often they are not as familiar with the day-to-day operational requirements for coverage, nor are they always familiar with the current trend, which must be kept in mind so that future requirements, as the oil field expands, are fully met. The Halliburton system was not all installed at one time. Installation took place over a period of approximately three years, usually on a Divisional basis. When designing the system for a particular Division, it was necessary to take into account the future systems of adjacent Divisions. This was necessary so that when these adjacent Divisions were installed a year or so later, major changes would not be required in the movement of towers, stations, etc. that lay along the boundary lines between the Divisions.

BASE STATION NOISE LEVEL

Wherever possible, base stations were placed at locations that had an ambient noise level of less than one-half microvolt as measured at the receiver input. A location would usually be designated satisfactory if no noise source exceeding one-half microvolt was found within a one-half mile radius of the proposed tower site when surveyed with a calibrated mobile receiver. The noise level at the tower site, when measured on the ground, is not indicative of the noise level that will prevail when the antenna has been placed on a 200' or 300' tower overlooking a much greater area of potential noise sources, hence the need for checking some distance from the proposed tower site.

In general, the Halliburton camps, like many oil field service company camps, are located near highways to facilitate movement of their heavy vehicles. Excessive noise from traffic or highlines along the highways quite often precluded the use of camp locations for stations except those that required a very limited coverage. In many oil field areas, the telephone line facilities for remote control of base stations are extremely limited and it was necessary to use radio relay for control purposes.

With the factors of noise, CAA restrictions, available phone lines, property, etc., affecting the final selection of a site, it is obvious that compromise often was necessary. Wherever possible, however, the last item to be compromised was the noise level at the base station.

250 WATT vs. 60 WATT BASE STATION TRANSMITTERS

If care has been taken to select a quiet base station location, the communication range normally will be limited by the so-called "talk out" range of the base station transmitter unless its power has been increased to compensate for the noise level prevailing at the mobile location.

Experience has shown that the noise levels prevailing at a properly sited base station and at the mobile unit are seldom equal in any Service, particularly the Petroleum Service. As mentioned a moment ago, wherever possible, base stations were located so that the over-all noise level was one-half microvolt or less. Experience shows that the noise level in mobile units traveling along highways is at least twice that of well selected

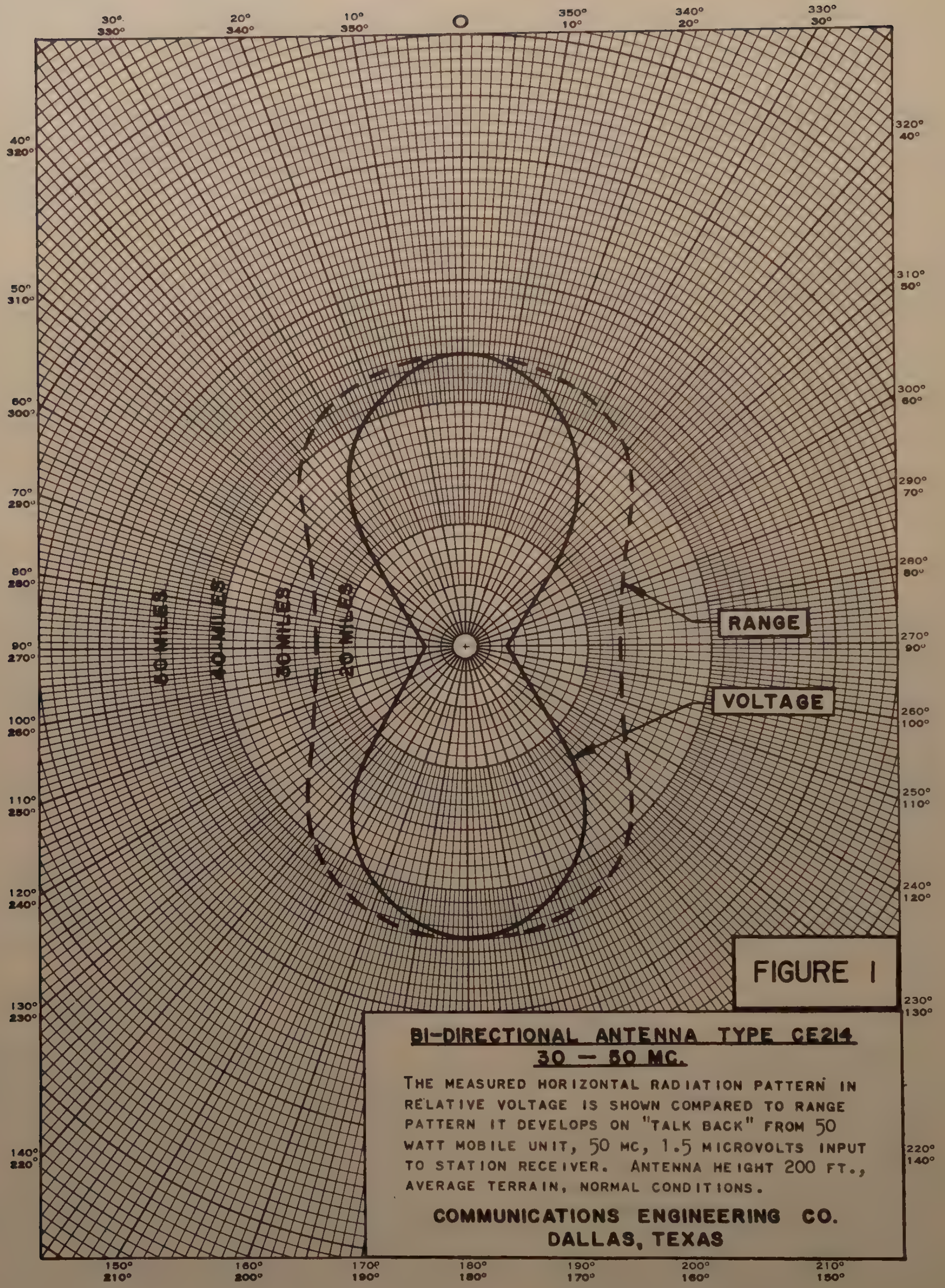

FIGURE I

BI-DIRECTIONAL ANTENNA TYPE CE214
30 — 50 MC.

THE MEASURED HORIZONTAL RADIATION PATTERN IN RELATIVE VOLTAGE IS SHOWN COMPARED TO RANGE PATTERN IT DEVELOPS ON "TALK BACK" FROM 50 WATT MOBILE UNIT, 50 MC, 1.5 MICROVOLTS INPUT TO STATION RECEIVER. ANTENNA HEIGHT 200 FT., AVERAGE TERRAIN, NORMAL CONDITIONS.

COMMUNICATIONS ENGINEERING CO.
DALLAS, TEXAS

base station locations. This condition is not improved at many oil well locations. The 2:1 ratio of noise voltage means approximately four times as much power is needed at the station. Thus, 250 watt stations for 60 watt mobiles— where maximum ranges must be covered.

Therefore, with a minimum differential in noise level of approximately 6 db, a 250 watt transmitter is desirable when the station must be operated at extreme ranges, once an economical tower height has been reached.

In general, until a tower height of approximately 160' has been reached, it is more economical to improve coverage by raising the tower height. This improves the talk-back as well as the talk-out range. However, once this tower height has been reached, the 6 db improvement can be more economically attained by increasing the base station transmitter power rather than by doubling the antenna height.

BASE STATION ANTENNAS

Base stations are seldom in the exact geographical center of the area to be covered. When the base station is "off center" a directive antenna may be used to alter the shape of the radiation pattern (for both receiving and transmitting The circular pattern of a non-directive coaxial or ground plane antenna may be changed to a pattern that more nearly fits the area of desired coverage. Approximately 30% of the antennas used in the Halliburton system were some form of directive antenna.

The use of directive antennas has several advantages:

1. It increases the signal strength over the desired operating area to provide greater reserve, thereby eliminating "dead spots", or it will permit a lower antenna height to be used for a given range. The use of a low antenna height reduces the cost of the antenna towers and may permit a station to be installed and operated at a location where CAA would not permit a higher tower.

2. Directive antennas can be used to reduce interference between users on the same channel or, in the case of the Halliburton system, they were used to reduce interference between adjacent operating Divisions.

3. In some instances, where the dominant noise source at a "noisy" location was from a direction substantially different than that of the desired operating area, the antenna directivity can be used to favor the signal and discriminate against noise.

In determining locations where the directive antennas could be used, it was necessary to use extreme care in laying out the operating area. Also, it was necessary to translate the patterns of the antennas into terms of range.

The usual pattern shown in values of relative power-relative voltage makes the antenna look very directive which in turn makes the range look attractive in the major lobes and poor in other directions. However, because the range of a system does not vary directly with the voltage or power of the system, the "nulls" and "lobes" of an antenna pattern are smoothed out when the pattern is translated into the terms of range.

Figure 1 shows the conventional figure eight pattern of a bi-directional antenna, which was used at a number of Halliburton locations. This drawing shows both the radiation in relative voltage (inside curve) and coverage pattern (outside curve) when translated into terms of range at an antenna height of 200' with a 50 watt mobile unit and a talk-back signal strength of 1.5 microvolts. Note how the figure eight voltage pattern is changed to almost a rectangle in terms of actual operating range.

In addition to use of directive antennas, special sidemount antennas were used. Because a high tower is one of the major items of expense in a system, arrangements were made, wherever possible, to mount antennas on existing towers of either other mobile systems, TV or broadcast stations, etc.

Properly designed directive antennas will not be materially affected by mounting on the side but conventional omni-directional antennas may have their radiation patterns seriously changed due to nulls in the horizontal or vertical plane, resulting from shielding or re-radiation from the metal tower structure. To overcome this problem, antennas were developed which consisted of folded dipoles fed in phase with integral mountings to keep them at fixed distances from the tower. The dipoles are staggered vertically on opposite legs so as to effectively produce a circular horizontal pattern. (See Figure 2).

ANTENNA APPLICATIONS

At Harvey, Louisiana the only location available by phone lines was limited by CAA restrictions to a maximum of 180' of tower height. Coverage was desired to cementing boats operating at the mouth of the Mississippi River approximately 90 miles south. Two six-element antennas fed in phase, having an over-all gain of approximately 13 db, were used for coverage to the south. In addition, a single ground plane antenna was mounted at the top of the tower which, with a second receiver and coaxial relay on the transmitter, provided general coverage from this same station.

A similar installation was made at the Tioga, North Dakota station, except that a single six-element antenna having a power gain of 10 db was used to provide coverage to mobile units near Wolf Point, Montana, and a sidemount antenna connected to a second receiver was used for general coverage. In both systems it was found operationally desirable to have two separate control units with two microphones so that the operator picking

up one microphone automatically transferred the antenna and muted the other receiver. Hanging up the microphones restored both receivers to full operation.

A special use of directive antennas was made at Newcastle, Wyoming. Telephone lines for remote control were not available and 100' due east of the Halliburton camp, where their 49.74 mc station was to be installed, was a station we had installed earlier for another company on 49.90 mc. Even with 60 watt transmitters, it was obvious there would be serious interference between the two systems due to transmitter radiated noise. Fortunately, the primary oil activity in this area was to the southwest and although both companies did require limited coverage in other directions, the maximum range needed was to the southwest. Leaving the other company's antenna non-directive, a special three-element Yagi was built for the Halliburton installation. This antenna when oriented to give maximum coverage to the southwest had a null of 30 db exactly in line with the other company's antenna. This attenuation was sufficient to effectively eliminate any interference between the two systems.

Halliburton's camp at Sterling, Colorado must provide service to a very large area of northeastern Colorado and southwestern Nebraska. To provide the necessary radio coverage it was necessary to use two base stations remotely controlled by radio relay from the Sterling office. One base station was located approximately 40 miles west of Sterling with a three-element antenna having 6 db gain toward the northwest. A second base station was located approximately 20 miles north of Sterling with a bi-directional antenna to provide coverage to the south and as far north as Sidney, Nebraska. Selection of the appropriate base station is made by shifting the frequency of the control transmitter. Separate receivers are used at the control station to constantly monitor incoming calls.

MAINTENANCE

Reliability is of great importance in all of the mobile radio services. It is of paramount importance in the widespread and remote operations of the Petroleum Industry. The Halliburton system is maintained under a flat rate maintenance contract which covers the furnishing of all materials, labor, etc. Such an arrangement has the advantage to the user that the only manner in which the maintenance company can realize a profit on the maintenance is to take all steps possible to reduce failures on the system. This incentive results in greater reliability for the user at no increase in cost.

Our records show that the majority of all service calls are due to tube failures. The tubes in most mobile equipment are operated under their normal ratings so that adequate emission reserves usually are available. Most tube failures, therefore, are due to shorts, open filaments, breakage, or other factors which are beyond analysis in routine inspections.

As soon as they became available about two years ago, we made it a standard procedure to install, at our own expense, the high reliability Five-Star tubes in all stations, even though until recently the non-availability of a Five-Star equivalent for the 6BH6 made it necessary to rewire some sockets. This has been quite expensive in view of the number of stations installed but our experience with these tubes so far indicates that the reduced failures over a period of 18 to 24 months will result in savings to us which will justify the cost of substitutions. Obviously, in some of the more remote stations, such as on Casper Mountain in Wyoming where maintenance in winter is accomplished on snow shoes, the payout should be sooner. In North Dakota and in Colorado, we even installed Five-Star tubes in the mobile units.

Except for North Dakota and Colorado, we are still using standard tubes for replacement purposes in mobile units. However, the standard tubes are being given 24-hour burn-in and vibration cycling before use. After cycling, all tubes are checked under the actual dynamic conditions in a transmitter or receiver. Standard tube checkers are apt to give misleading information on tubes to be used in mobile service and we have found them of such limited value we have no tube checkers in our maintenance equipment. We strongly feel that the best method of checking tubes is the substitution method.

In addition to the use of Five-Star tubes, certain other techniques were found to reduce outages. West Texas and Panhandle dust on relays was a particular problem. It is now standard to install dust covers on all exposed relays.

At all base stations which were controlled by means of radio relay, voltage stabilizers are used to maintain a constant primary voltage on both the base and fixed receivers. This permits the squelch operated relays to be set much closer without danger of false operation due to line voltage changes.

Also, on radio controlled stations a time delay circuit was used on the base station receiver operated relay. This is so connected that the fixed relay transmitter remains on approximately three seconds after the last transmission either into or out from the base station. Thus, during the course of a conversation, the relay transmitter carrier remains on, so that when the mobile transmission is received there is no delay after the initial transmission. This avoids losing the first word of mobile transmissions. This was done primarily as an operational measure but it is believed the reduction in keying of the relay transmitter tends to reduce its maintenance.

Although all 250 watt stations are designed with automatic overload relays, 60 watt base stations normally use fuses for protection. In some areas where there were excessive fuse failures due to surges, corrosion, etc., we installed automatic resetting overload relays on the 60 watt base stations and 35 watt relay stations.

For lightning protection it has been our practice to install the pellet protector across all base station input power lines. This is in addition to the installation of grounding rods and grounding stubs on the antenna lines.

As a further precaution against lightning damage, we use solid dielectric coaxial cable rather than gas filled lines on all installations below 450 mc. In terms of range at 50 mc using a 300' tower the difference in efficiency is only 2%. This will have negligible effect on performance of the system and our experience gained in using many thousands of feet of antenna line indicates greater reliability with the solid dielectric line.

Even with proper bonding of the gas filled line to the tower, lightning can still cause pin-hole leaks. Once a line has lost its pressure, its efficiency suffers materially and can only be regained after drying by bleeding of the line from the top and repressurizing.

Several years ago we experienced some difficulty with the solid dielectric line due to contraction of the center conductor during cold weather. Consultation with the manufacturer developed that a long center pin was available to allow for this contraction in the fitting. This is now used on all installations. As a further precaution against contraction of the center conductor, we clamp two radiator hose clamps securely around the cable just below the fitting. This tends to prevent any change in the relationship between the center conductor and the outer shield and insulation.

I have tried to outline a few of the points that we have found useful in reducing maintenance on the system. I cannot emphasize too strongly the value of proper maintenance records. There are many unseen maintenance costs which are not always apparent unless accurate detailed records are kept. Our company recently has expanded its record keeping on all of the some 100 systems we maintain. A firm specializing in semi-mechanical methods of recording and statistical control assisted us in the development of a system which was installed several months ago. It is already providing its value.

Obviously, the administrative cost of keeping such records and analysis is considerable but we firmly believe that it is absolutely necessary if failures and hence maintenance costs are to be kept to a minimum.

At the outset of this paper, I mentioned that we had not yet found all of the solutions to some of the problems in connection with this system. I would like to close by mentioning the most serious problem we have encountered in this system is that of skip interference between the various Halliburton Divisions. In June and July operations in the Indiana and California Divisions were seriously compromised for several hours each day due to the severe interference they were receiving from some 70 or 80 of their stations talking to some 800 or 900 mobile units in the Midwest.

Where possible, we have installed or modified existing directive antennas in an effort to reduce the effects of skip interference. The best weapon against skip has been found to be tighter operating procedures, keeping conversations at an absolute minimum.

In spite of these measures, skip remains a problem, not only for the Halliburton system but

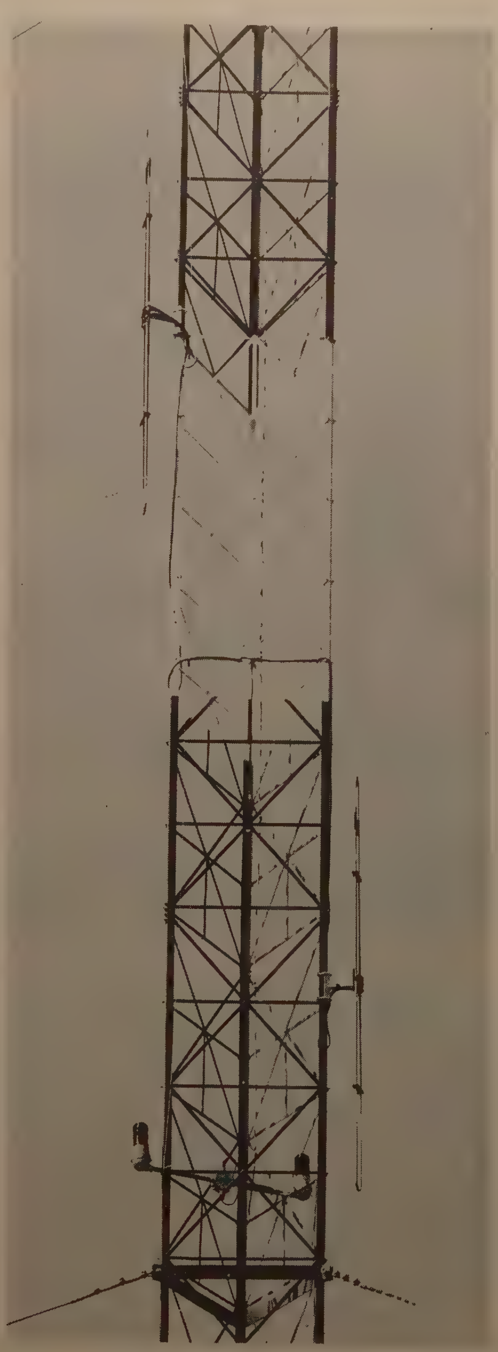

Fig. 2 - "Side mount" antenna, type CE-212. (30 - 50 mc)

for all mobile users in the 30-50 mc band for several years to come.

Therefore, in closing, I would like to broaden the scope of this paper to observe that the tremendous occupancy of the 30-50 mc band over the past few years, following our most recent sun spot peak of 1947, will result in very serious skip interference as we go back up on the sun spot cycle. Because petroleum operations require the extended coverage possible only in the 30-50 mc band, it will not be possible for them to move to high frequencies just to avoid the skip interference.

I sincerely believe that this matter of skip is one which will require considerable study on the part of all engineers. Whereas there may be little likelihood of finding a complete remedy to skip, close cooperation by all users, both as to operating practices, system design, etc., may help in the reduction of interference to operations.

LICENSE OR LICENSE

Edwin L. White
Federal Communications Commission
Washington, D. C.

Although a big dictionary is devoid of plot and has very little love interest, it often provides interesting reading. It is full of nuggets of knowledge, such as that zythum is a kind of beer and that zymurgy is the long-hair term for the brewers' chemistry. The theme of my talk today stems from the definitions of the word "license."

I presume that most of us when we hear the word "license" think of the document which the bureaucratic Commission in Washington grants or withholds on the basis of some obscure whim. And more often, probably, we grumble about the things we cannot do under such a license than we rejoice over the things we may do.

A license document is not the only thing covered by the word "license." The dictionary says that license is "authority or liberty given to do or forbear any act; permission to do something specified; especially, a formal permission from the proper authorities to perform certain acts or carry on a certain business which without such permission would be illegal; also the document embodying such permission."

The dictionary also states that license is "Excess of liberty; freedom abused." We have had experience in the radio field with both.

Radio was regulated for many years before a document covering the use of radio existed. The first radio treaty was formulated by a conference held in Berlin in 1903. One of the most important results of that conference was the adoption of a regulation which still exists, that ships on the high seas must intercommunicate with each other without regard to the make or ownership of the ship or its radio equipment and that ship radio stations must give absolute priority to distress calls. The adoption of the treaty regulation was due directly to abuse of freedom. Before it was adopted Marconi would not talk to Telefunken, nor would Telefunken talk to Marconi. Distress calls were only honored if the ship in distress belonged to the same steamship line as the recipient of the distress call. Now-a-days such abuse of freedom seems incomprehensible, but once it was so frequent that it resulted in a treaty.

The radio act of 1913 provided for the licensing of radio stations for the first time. These licenses were to be issued on application by the Secretary of Commerce and Labor. (At that time the two present departments were one.) The Act provided further that the document should "state the wave length or the wave lengths authorized for use by the station for the prevention of interference and the hours for which the station is licensed for work."

In 1921 the Secretary of Commerce refused to grant the Intercity Radio Company, Inc. a license on the ground that he was unable to ascertain a wave length for use by Intercity which would not interfere with government or private stations. Intercity appealed. I will not try to give a lawyer's analysis of the decision of the court. However, the net effect was that the Secretary of Commerce had no authority to refuse a license, that he was required to issue a radio license to all applicants who met the requirements set forth in the Act and that the only discretionary authority he had was to select a wave length which would create the least possible interference.

In an endeavor to keep some order in the use of radio, the Secretary of Commerce then interpreted the phrase, "the hours for which the station is licensed for work" to give him the power to divide the usage of wave lengths on a time basis among different licensees. This presumed power was used as a means to attempt to reduce the interference problem.

Zenith Radio Corporation had been licensed to broadcast from 10:00 a.m. to 12:00 p.m. on Thursdays. It proceeded to broadcast during other hours on other days. The government dragged Zenith into court. Again, I will not try to make an analysis of the court's order which found Zenith not guilty. However, it was generally to the effect that the Secretary's power to control interference on a time division basis was at least questionable.

With these court decisions, the Secretary of Commerce found himself in a position of being unable to refuse licenses and with doubtful authority to impose any conditions in licenses to avoid interference. As a result broadcast stations sprang up all over the country. They operated when they pleased and were licensed on any frequency that suited their whim for which they applied. There was an excess of liberty and freedom was abused. In a short time the air was so full of whistles and squeaks that practically no one had broadcast reception. As the previous case of abuse of freedom, license if you please, brought about a treaty, this recurrence of excess of liberty, again license, so disturbed Congress that talk was translated into action and in 1927 the Federal

Radio Act was adopted. Since that time not only has the FCC been established but rule has piled on rule and regulation on regulation to a point that some claim a proverbial Philadelphia lawyer is required to cope with the legal problems involved in running a radio station.

For years we were troubled by rugged individualists who operated without a license or committed other acts which infringed on the rights of others. For example, the Governor of one of our great states defied the Federal Government at one time. He stated that he was going to run the state police radio station as he wished and, if necessary, he would turn out the National Guard and eject any Federal Radio Commission inspector that interfered. Fortunately, everyone calmed down before any overt act had been committed. Peace was finally restored after this state had experienced interstate interference and with the help of the Federal Radio Commission obtained relief.

Occasionally someone will talk big and threaten to take the Commission to court and challenge its jurisdiction over the VHF, UHF or SHF. When it is pointed out that if he has a license he is entitled to protection, he usually changes his tune.

Again we have people who say "Ah, let them all in and fight over the frequencies."

If in any single service where we have a large number of potential customers, and we do in all services, we should let them all in and let them fight over the channel, I think it is quite obvious that, considering human nature, the service would disappear. You need not look far for examples. If any of you have lived on a party line, particularly if the parties on the other line have teenage children, you personally will have experienced what I'm talking about. Quite frequently we hear of homes burning down or people dying because some person was occupying the party line telephone and refused to get off the line to let the party in distress call the fireman or the doctor.

We sometimes hear the sophistry that he is best governed who is least governed. It is probably a natural reaction to those who have experienced contact with the fallacy that the government always knows best. If the millennium were here, we might possibly be able to do without rules and regulations. In that happy event everyone will be able to do what he wishes with radio within its capabilities, and no one will think of deliberate interference, slander, obscenity or any other of the acts which are now prohibited by law. Since the millennium has not arrived and since we find ourselves in the position where we must deal with a limited spectrum and with real people having normal urges and inhibitions, it is necessary to find that point which is the most realistic division between over and under regulation.

I can assure you that the bureaucrats in Washington are doing their level best to find this point. But it is not easy. Beginning with the prohibition amendment we have been going through a phase wherein there has been general public clamor for law to cure all ills, real or fancied. We have felt this in the Commission through the receipt of letters, petitions, telephone calls and visits from those who think that the Commission should require this or prohibit that.

Our modern day lives are so complex that it would take the wisdom of Solomon for anyone to adopt a set of regulations that could equitably provide for the use of radio suitable to the individual needs of the myriad licensees in each of our services. If we found a man with the capability of writing such regulations, they probably would take more shelf space than the U. S. Code and it would take scores of Philadelphia lawyers to find out which regulations fitted any particular applicant or situation. Of necessity, therefore, the best we can hope for is to meet the needs of the majority and leave everyone equally dissatisfied.

As a practical matter this problem may be incapable of an ideal or permanent solution. Certainly the Commission alone cannot reach such an answer. However, I believe that cooperatively the various services working with the Commission can do much to avoid abuses of freedom and through self regulation the necessity for government interference can be reduced to the minimum. The Commission has no expectation that it will ever assemble a staff large enough to know all of the details of all of your businesses. The occupancy of the radio spectrum is growing by leaps and bounds. One to two thousand new communications systems are being authorized each month. Something must be done each day to keep pace with this changing picture or chaos will ensue.

The Commission must continue its current program of maintaining the greatest possible familiarity with the way business is conducted in the country so that its regulations can be as simple as possible, its licensing as free from restrictions as practicable, and its rules and regulations simple and appropriate so that all of those entitled to use radio in the public interest may determine their rights and obtain them with a minimum of difficulty.

You, the users of the spectrum, must put your shoulders to the wheel. Support your associations and frequency assignment groups in their efforts to get the most for all out of the limited number of frequencies available. When you feel the need for rule changes, propose them. When the Commission proposes rules, study the proposals and send in comments.

Together through license let us avoid license.

A THREE CHANNEL COMMON CARRIER RADIO MOBILE SYSTEM TO SERVE INDUSTRY

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Summary

To show the Communication Engineer's role in American Industry, an example is made of the engineering, installation and maintenance of a three-frequency mobile system covering the oil basin of Indiana, Illinois and Kentucky. In this instance, the so-called "Tri-State" Mobile Telephone System, it was first necessary to determine the Industry's communication needs; analyze these data, manufacture specific equipment, establish transmitter sites and control points and set up traffic handling procedures.

The need for the system was two-fold. An area adjacent to an existing general highway mobile cell needed to be covered and the existing cell was overloaded. Another cell on the same frequency would only aggravate conditions in the overloaded portion.

The new "Tri-State" system was devised so that each of nine base stations operated on one of three frequencies. Since, at the time the system was being engineered there were no three-frequency mobile units available, a special set had to be designed and manufactured to meet the requirements of the system. Co-channel overlap was alleviated in this system by making no adjacent cells operate on the same frequency. The customer was required to select the right channel as he moved across the area.

Studies made of actual results indicate that more traffic is being handled per station in this system than in the usual area coverage (highway) system.

Only through cooperation of user, manufacturer and supplier together with their engineers could an adequate system have been provided.

Members of the Vehicular Group and Friends

As an example of the Common Carrier Communication Engineer's role in American industry, I will describe the engineering, installation and maintenance of the three frequency common carrier mobile system which now serves the oil basin of Indiana, Illinois and Kentucky.

The first common carrier mobile station was placed in service in 1946. At the end of 1953, in the United States, there were 314 Common Carrier stations, of which 138 operate in 35-44 MC Highway channels and 176 operate in the 150-160 MC Urban channels with a total of 13,000 mobile units. Plans are being made to use the UHF channels to relieve the larger metropolitan areas. Urban channels are used in and around large metropolitan areas to provide maximum channels to handle the heavily concentrated traffic. The Highway system is used to give coverage over extended areas serving persons whose mobile requirements may be beyond the range of a single station.

First, I will describe a typical Highway mobile cell so that you may more fully realize the problem that was facing the communication engineers in the Tri-State Oil Basin.

A Highway cell generally consists of a 250 watt base transmitter with 135 foot antenna structure. The land receivers are pole mounted satellites so that the 30 watt mobile sets more nearly equal the coverage of the base transmitter. A remote control terminal is located in the telephone company central office. The terminal has the necessary circuits to terminate the transmitter and receiver lines with the toll switchboard, where the circuit can be operated in the same manner as a regular toll telephone circuit. The control terminal also has a two tone selective signal oscillator for selective signalling of the mobile units and a voice operated gain device to adjust the voice level into the land transmitter for the differences in land wire transmission level.

The mobile units are commercially manufactured 30 watt sets with the addition of Western Electric two tone selector sets for selective signalling. The control units consist of a hand set and a call light and bell indicator.

Overlap between stations is necessary to give complete coverage of an area. Since the land transmitter is on throughout the conversation if both stations are transmitting at the same time, interference will be experienced by a mobile unit in the overlap. To mitigate the effects of overlap, an interference coordinating circuit is used, (Figure 1). This is a land wire signalling circuit between the operators of adjacent stations, which indicates when the adjacent station is transmitting. By observing this signal and monitoring her own channel the operator knows if a mobile subscriber's call is being handled by an adjacent station. A mobile subscriber may travel from one cell to another and get complete coverage during the interval he passes through the overlap area. Of course, during this period only one of the overlapping stations can be on the air so that traffic cannot be handled by the other station.

The need for another common carrier general mobile system in the Tri-State Oil area developed because of the large overload on the

Evansville Highway station, which required relief to handle offered traffic and to care for a long waiting list for mobile service.

Three Telephone Companies cooperated in establishing the mobile system in the Tri-State Oil Basin which extends into Indiana, Kentucky and Illinois. The area encompasses 15,000 square miles. Activity within this area varied with the oil drilling. Since many of the same concerns followed the drilling, it was apparent that an adequate mobile service must allow for a free flow of mobile stations throughout the entire territory.

Surveys were undertaken by Sales Engineers of each of the three companies. The surveys were designed to discover both the number of mobile stations required and the coverage desired by each customer. Prime and fringe coverage areas were plotted on charts, which were divided into 15-mile squares. Analysis of these data indicated the areas in which it would be economically feasible to provide service.

With the area to be served established, detailed system planning began. Some of the factors which influenced the choice of system were as follows:

1. Economy

It was necessary that system costs be held down because of the great demand on capital for land wire service and also so that a return on investment might be realized. These factors dictated simplicity of design.

2. System

For complete coverage, base station separation must result in overlaps. Wire facilities for coordination circuits were almost nonexistent, so a radio system which could be properly operated without coordinating circuits, was indicated.

3. Frequencies

In the 35-44 MC Highway band one channel was available. This was in use at Evansville, Indiana and Centralia, Illinois. The Evansville station had more traffic than could be handled. It was felt that the addition of stations on this channel would lead to worse conditions at Evansville; would require coordination circuits, and would not provide the necessary traffic relief nor provide for growth.

In the 150-160 MC Urban band there are six duplex channels spaced 60 KC apart which are allocated to common carriers. Using three of these channels, a system was devised where no adjacent cells would be on the same frequency. Visualize a grid of equilateral triangles with a station of a different channel on each point of the triangle, (Figure 2). This system, which can theoretically be extended to infinity, permits all adjacent stations to be on different channels.

With this method in mind, the Transmission Engineers of each Company determined the approximate location for each station site.

Twenty mile circles were drawn in a pattern such as described, and the topography of locations near the centers of the circles was studied. The better sites were considered in relation to elevation, wire facilities, roads and noise level. Sites were picked near Effingham, Clay City and McLeansboro, Illinois; Vincennes, New Harmony, Evansville and Rockport, Indiana; and Morgansfield, Kentucky, (Figure 3).

It was originally felt that because a Highway cell was already located at Centralia, Illinois, Urban coverage was unnecessary there. Later this station was added to the Tri-State system to give complete coverage to the Urban subscriber.

Since each company had its own engineering problems I will elaborate on special problems faced by Illinois Bell.

Of the four Illinois stations, wire lines to connect the radio facilities to the control points were available at Centralia and Effingham. The McLeansboro site was within a quarter mile of telephone lead, so only a short land line had to be constructed. The Clay City cell was entirely a different story. It was desired to operate the Clay City station from Effingham. The Clay City cell operated on a four wire basis, with one pair used for transmitting and one pair for receiving. Since the Effingham-Clay City telephone toll lead was routed through several towns, construction costs would have been prohibitive.

The Clay City wire line problem was solved by use of a Lenkurt open wire carrier on the existing toll lead. This carrier had a four wire option and provided two DC signalling circuits. This gave the necessary transmitter control in one direction and the receiver signalling lead in the other. Thus with one carrier system both the voice facilities and DC control circuits were realized without new outside plant construction.

Because of circuit charges and the expected life of the oil field, it was imperative that the station cost be kept down to give rates comparable to those in the existing Highway cells while still receiving a fair return on the investment. At this time a so-called "packaged station" was decided upon. This consisted of a single 60 watt transmitter and a single receiver at one location, using one antenna support for both transmitting and receiving antennas, (Figure 4).

Because common carrier general telephone service has more stringent transmission requirements than private mobile systems, a somewhat stronger signal should be received by the land subscriber than the mobile subscriber. The reasoning behind this is that a land wire subscriber is unaccustomed to "push-to-talk" radio transmission and this coupled with a poor signal might greatly disturb him. On the other hand, the mobile subscriber would be more accustomed to this type transmission and would consider that if he had trouble hearing the base station the base station

would have trouble receiving him. In the Illinois stations, the receiving antennas were mounted fifteen feet above the transmitting antenna to increase the receiving range, (Figure 5). This also gave the necessary decoupling between the transmitting antenna and the receiving antenna, preventing desensitization of the receiver. This alleviated the need for a stub with its resulting transmission loss to keep the transmitter signal out of the receiving path. At the time of engineering, considerable thought was given to the use of a diplexer and a single high gain antenna. However, the cost of this equipment made it more economical to use the previously mentioned method. Indiana stations have locally assembled diplexers which have proven quite satisfactory even though extra range of the transmitter over the land receiver is apparent. The directivity of the tower in Illinois stations is noticeable but is of little consequence.

Because the land line must be connected to long toll lines, transmission levels must be closely controlled. In the usual highway system, a test transmitter is located at the control terminal. By putting a tone of a given level on the test transmitter carrier, the land receiver volume can be set to give the required level to the land line. It was not considered economical to put a test transmitter at each control terminal in the area so a single three frequency transmitter was located at the existing tower at Centralia. This was controlled by a metallic simplex lead from each remote control point. The control point at Centralia was given the voice facilities to sign the station. With this system any of three frequencies can be dialed from each of the control points either with or without a thousand cycle tone.

At the time the Tri-State system was engineered there were no three channel mobile sets on the market. Two manufacturers were contacted and our problem was presented. One manufacturer stated that with a minimum of engineering a new three channel set could be developed using available equipment and a small adapter chassis. This set was produced and used in the system. While using the set the customer must remain aware of the cell in which he is operating and keep his channel switch thrown to that channel so that the land line party can reach him.

The Tri-State system was cut into service in December, 1952. The following statistics indicate the efficiency of this three channel area covering system in comparison with the Highway single channel area covering system:

TRI-STATE USAGE COMPARED WITH HIGHWAY USAGE FOR FIRST SEVENTEEN MONTHS

OF TRI-STATE OPERATION FOR ILLINOIS

	Highway	Tri-State
Total Number of Calls	137,135	78,006
Total Number of Messages	107,089	55,552
Per Cent of Calls resulting in completed messages	78%	71%
Average No. of Calls per Month per Cell (Tri-State 57% higher than Highway)	733	1,147
Average No. of Messages per Month per Cell (Tri-State 43% higher than Highway)	573	817

The per cent of calls resulting in completed messages may be lower for the Tri-State system because many customers whose vehicles travel from cell to cell throughout the oil basin may frequently neglect to keep their mobile unit channel switches turned to the right channel. This causes more "don't answer" when calling the mobile unit. The preceding information is based on toll tickets prepared by operators at the time calls are placed from land lines to mobile units or when mobile units are calling either land lines or other mobile units.

Maintenance costs have been 11% lower on the Tri-State system than the Highway. Two of the reasons are:

1. All equipment is of the same type. This minimizes the supply of spare parts needed.

2. Standardized equipment becomes familiar to maintenance forces and leads to rapid repair work. In the Highway system sets of many different manufacturers are used and equipment types range from early 1946 designs to the latest models.

Land transmitter outage due to power failure has been reduced by adding emergency generators in two of the cells. In the Centralia cell, emergency power already existed and Effingham cell uses power which is considered sufficiently dependable.

Conclusion

The Tri-State mobile system was designed to give common carrier mobile telephone service to a particular industry and its associated businesses. It was necessary first for the industry to present its communication needs. Sales engineers conducted surveys to determine the exact area to be covered. Communication engineers of the various telephone companies operating in the proposed coverage area, then worked together to design one system which was compatible to the entire territory. Engineers of the various equipment suppliers and manufacturers worked together with the communication engineers to meet the equipment requirements and service dates.

Only through complete cooperation of all of these engineers was a system such as the Tri-State Mobile Telephone System realized.

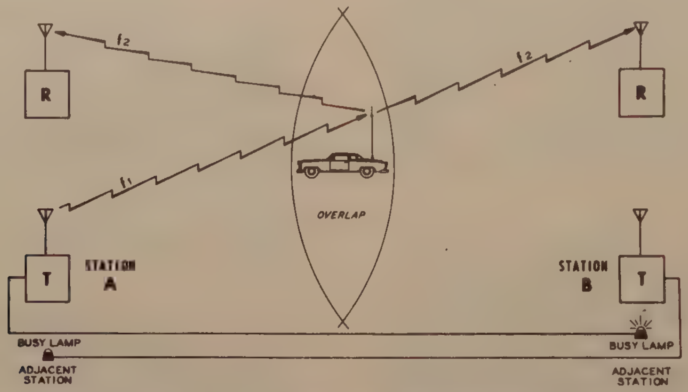

Fig. 1 - An interference coordination circuit used to indicate existence of an overlap condition between station A and station B. The operator at station B views her busy lamp and notes that station A is handling traffic. By monitoring her receiver R and hearing conversation from the mobile unit she knows that the unit is in the overlap area (that area where the signals received from both the land transmitters have a differential of less than 6 db). Therefore, operator B cannot handle traffic through her station. To let other mobile units in her coverage area know that she is in an overlap condition and unable to handle traffic, operator B places a busy tone on her channel. She does not energize her transmitter until she hears the mobile unit in the overlap area talking. In this manner operator B avoids interfering with the handling of overlap traffic by station B.

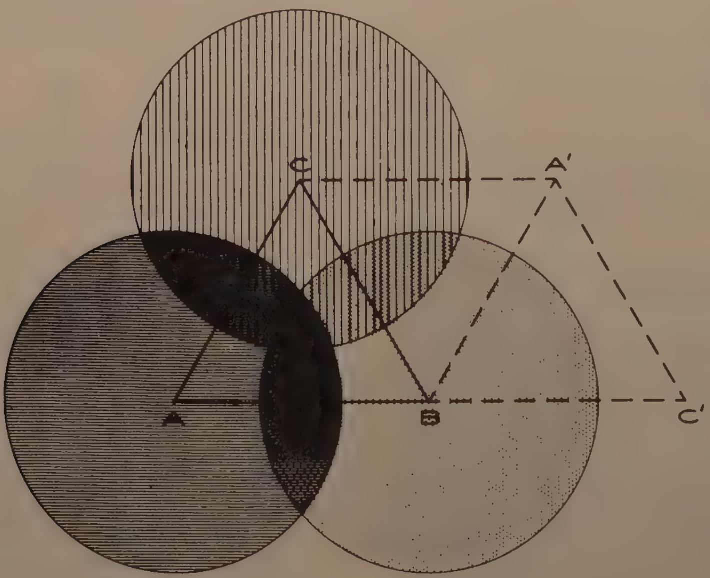

Fig. 2 - The method used in the Tri-State to overcome overlap. Station A' is the same channel as station A. There is no same channel overlap but there is solid coverage of the area with at least one channel and in many places with two or all three channels.

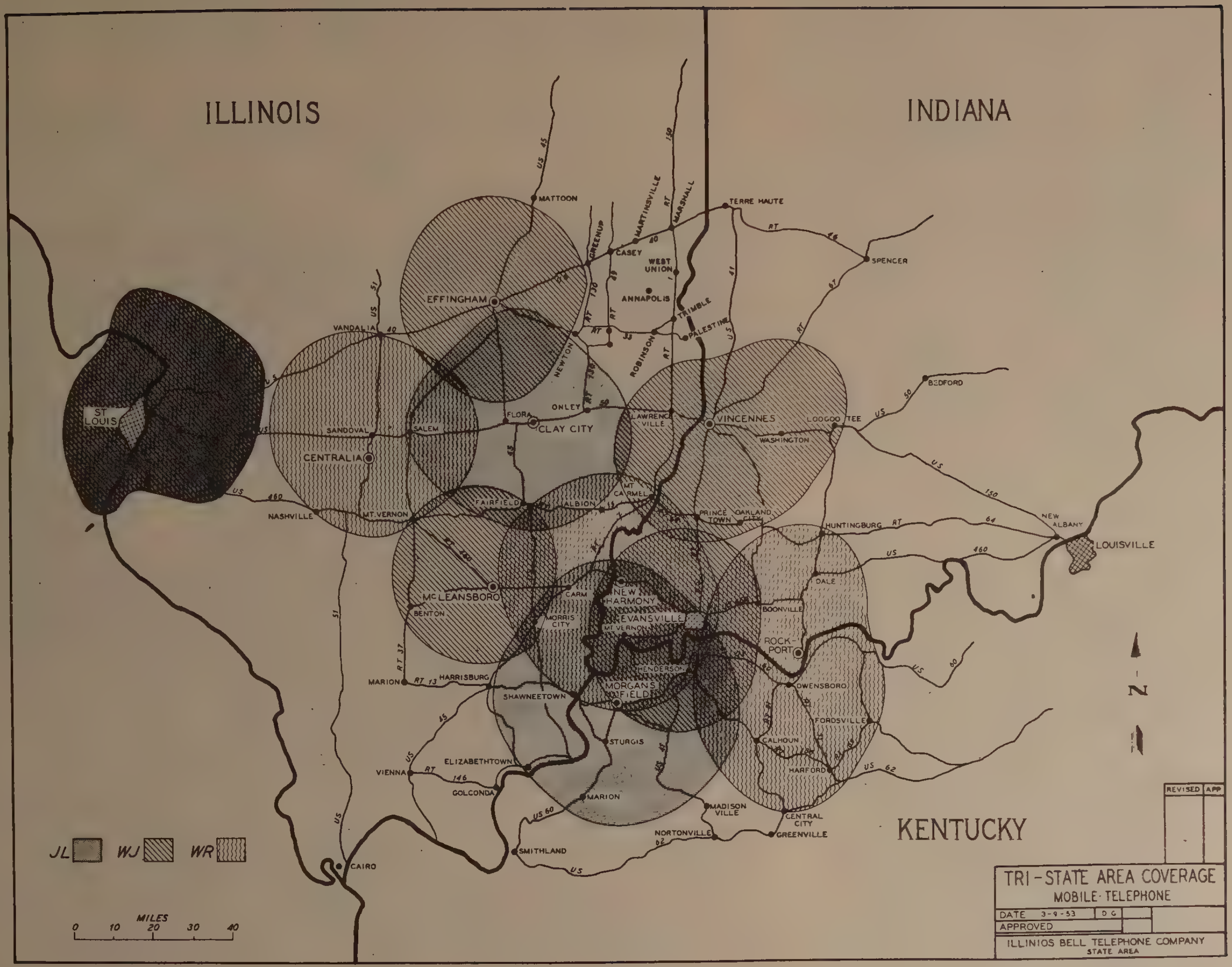

Fig. 3 - The Tri-State system coverage after installation.

Fig. 4 - An average "package station" installation at the McLeansboro, Illinois station site. On the right is the self-supporting antenna tower; in the center the transmitter, receiver and land wire terminating equipment; and on the left a 2 kw emergency engine driven alternator.

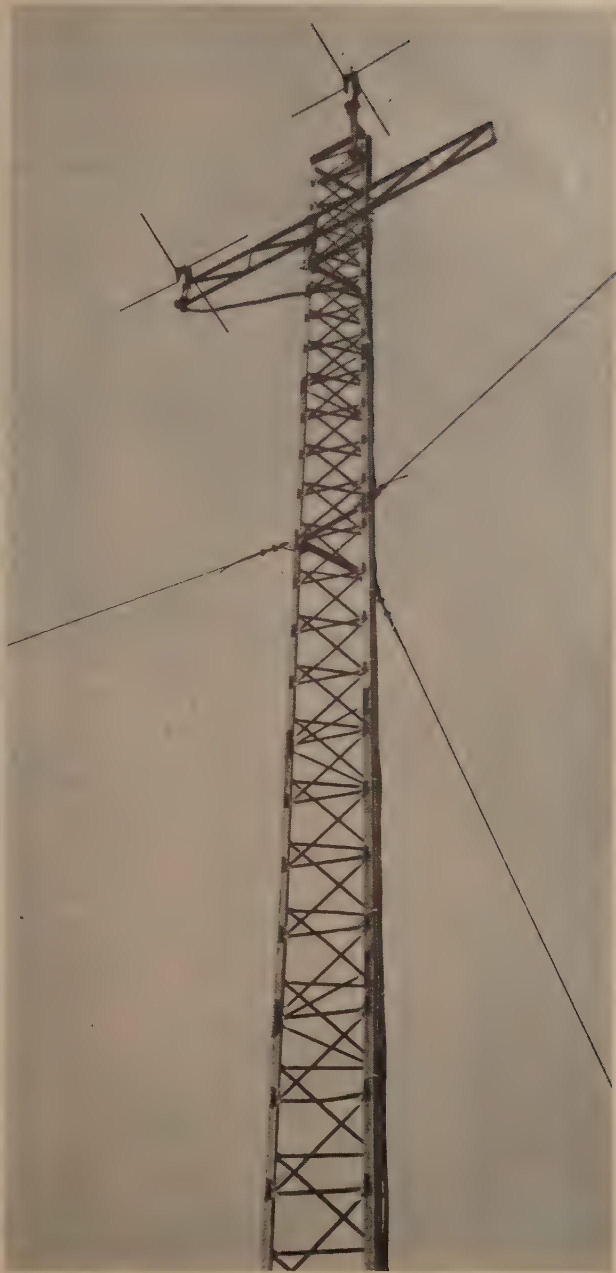

Fig. 5 - The transmitting and receiving antennas at the Effingham, Illinois station site. The receiving antenna is mounted fifteen feet above the transmitting antenna to give greater receiver range and the necessary decoupling between the antennas.

EFFECT OF FRONT END RECEIVER DESIGN ON OVER-ALL PERFORMANCE*

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During recent years we have heard more about low IF selectivity, low IF amplifiers and adjacent channel reception than we have about any other features and any other portion of the communications receiver. Still it is obvious from studying field problems that the majority of operating difficulties in which the receivers are involved are most frequently tied up with the front end of the receiver. Also it is obvious that a very considerable portion of the receiver cost and size is made up of components involved in the front end of the receiver. Since we are spending valuable space and money on this portion of the receiver, it is important to recognize just how much this part of the receiver contributes to over-all performance. In other words, is this the portion of the receiver which really deserves serious consideration when we look ahead and foresee the problems facing us in the future due to the large numbers of users being licensed every year?

Typical field situations which involve the front-end performance are desensitization due to a nearby transmitter and intermodulation. The intermodulation type of interference may result from the operation of several adjacent channel stations in the same area, or from stations in the same area which have equal frequency spacings. As the communications bands become more and more populated this will become more and more often the case. So, with an eye to the future, let us now consider the important functions performed by the front end of the receiver.

In considering the effects of front-end design on the receiver and resulting systems operation, we shall include only the high IF and the rf amplifier. Let us begin by looking at a receiver performance curve (Fig. 1) and observe the spectrum on each side of the desired frequency, where the front end determines the receiver performance.

Curves A and B of Fig. 1 (the inner curves) show the basic selectivity of a receiver and curve C shows a typical performance curve or two-signal selectivity curve. Although this curve will be explained in more detail later, we will note for the time being that the performance curve is taken out to six 40 kc channels on each side, and at this point the performance curve has somewhat leveled off showing the ultimate performance of the receiver. At this time I want to point out that low IF selectivity is involved in determining channel 1 and thereafter, front-end performance determines the db level attained at each of the other channels. From this it becomes evident why front-end performance is so frequently involved in field problems resulting from other systems not on adjacent channels, but more often fifty channels or more removed. Certainly we are going to encounter more neighbors over this range than we will on adjacent channels. This curve then shows us why front-end performance becomes so important as we look to future operating conditions which will put many more stations on the air and give us more neighbors in the frequency spectrum. There are only two chances for adjacent channel interference and fifty or more channels on each side of the frequency to which the receiver is tuned, the performance of which is determined entirely by the design of the front end of the receiver.

We are frequently led to believe and naturally inclined to think (due to the original tuned radio frequency receiver) that the selectivity curves of Fig. 2 represent the performance capabilities of a communications receiver, whereas they only represent the inherent selectivities of all the tuned circuits (principally the low IF), without taking into account the fact that these tuned circuits are connected together, or linked together, with nonlinear devices like vacuum tubes. One need only put several communications stations, even though separated by five or fifty channels, on a mountain top or a building to realize the error of thinking that the curves of Fig. 2 represent the receiver performance. Note that this type of curve indicates essentially infinite selectivity performance at the alternate channel and, therefore, we cannot afford to use these as the basis of our thinking or our specifications. In order to read performance from the selectivity curves of Fig. 2 we would have to completely alter the design of our present communications receivers and put a major portion of the selectivity shown by these curves in front of the first grid. Such receivers have been built and, in another branch of the communications field, are currently being sold and used to good advantage. Why don't we in mobile communications use this kind of a receiver? The answer is simple; if we did we could not at present obtain the size or the sensitivities which are acceptable for mobile communications. Such receivers are widely used in the carrier current field where they operate much lower in frequency and they are not interested in sensitivities better than 100 to 200 microvolts. It is interesting to note that this ideal type of receiver was manufactured and sold in large numbers back in 1926 and 1927 for use as a household or entertainment type of receiver.

Before going into the basic considerations of the high IF or rf amplifier, we shall briefly study Fig. 3 which shows the basic relations in bandwidth or selectivity of the rf, high IF and low IF ampli-

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fiers. This mental picture is important for a better understanding of the performance characteristics of a mobile communications receiver. These selectivity curves were taken from a receiver which has relatively very high rf selectivity in order to get the rf selectivity to show on a ±500 kc base. Since there are such wide differences in the operating frequencies and side wall slopes, and since these widely different amplifiers must be related to each other by means of a converter, it can readily be appreciated that numerous problems will be encountered in making a receiver of this type sensitive and at the same time have essentially the characteristics of a single-frequency amplifier. In other words, we are in effect trying to transfer to the rf amplifier the inherent selectivity of the low IF amplifier so as to make it appear that this selectivity occurs in the front end, the frequency of which may be 50 mc to -150 mc or 450 mc. These problems are the major hurdles encountered in the front-end design, and the two signal performance curve shows to what extent we have been successful in transferring the selectivity of the low IF amplifier to the front end or operating frequency of the receiver.

The High IF Amplifier

In analyzing the high IF amplifier let us consider: Why we have a high IF amplifier, and what functions this amplifier performs; next, the factors affecting the choice of the high IF frequency, and the selectivity and the gain in this amplifier; and, finally, how these factors enter into the over-all performance.

In the present state of the art, we have a high IF amplifier largely because we do not know how to get along without it. That is, we do not know how to take the big step down in frequency from the front-end frequency to the low IF frequency without getting into many more troubles than the ones we will encounter due to the extra converter. Let us say for the time being that we could not make our receivers sufficiently "one spot" in performance.

The high IF, in broad terms, acts as a reducer to step down in frequency and bandwidth from the rf to the low IF frequency which is usually in the order of one-half a megacycle. It also has some gain and, therefore, helps in a minor way to avoid having essentially all the gain at the same frequency, namely, the low IF frequency. When first used in receivers, high IF amplifiers were employed principally to avoid having the large values of gain required in FM receivers at one operating frequency. This then helped to avoid regeneration difficulties; however, our ideas today in regard to the high IF amplifier in mobile receivers are quite different.

As early as 1938 it was common knowledge in engineering circles that a gain of only three to five was adequate at the lower frequencies in an rf or high IF amplifier to over-ride the noise of a converter. Consequently, where difficulties due to spurious responses and inability to obtain high selectivity in an rf or high IF amplifier was a problem, the gain was reduced as required.

In utilizing this reducer in bandwidth and frequency we need to perform an additional conversion which is advantageous, although an inherent trouble maker. Let us how consider factors which affect the design of the high IF amplifier. The principal factors are: (1) the image at both the first and second converter, (2) spurious responses due to harmonics of the IF frequency when the receiver is exposed to off-frequency signals, (3)

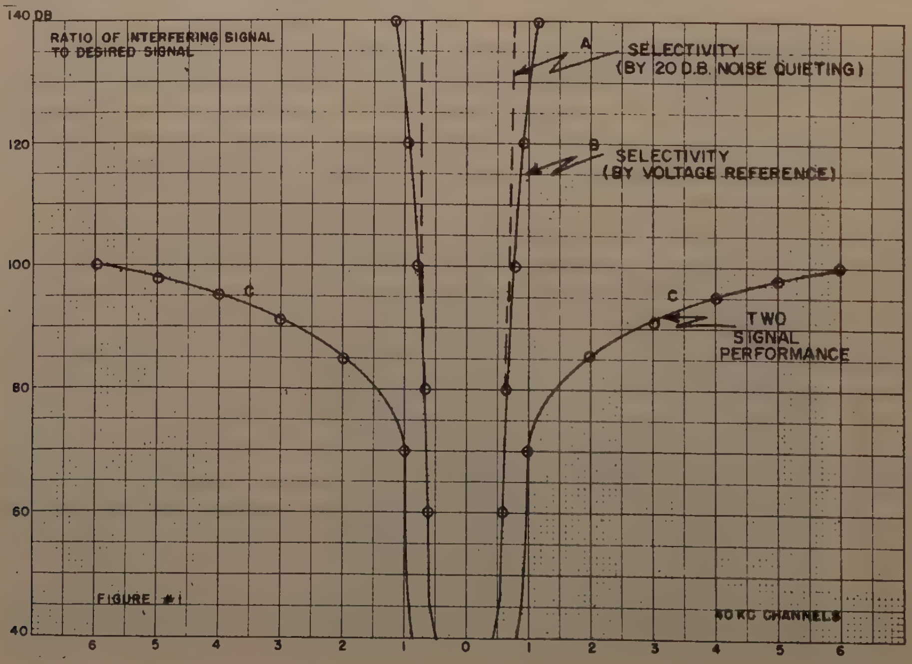

Fig. 1

spurious due to the multiplications of the second and first crystal frequency, (4) spurious due to half the low IF frequency, and (5) the frequency of the high IF amplifier determining the frequency range of the mode crystals when mode crystals are used for the first oscillator. We will consider these factors in more detail, taking the last one first.

For receivers in the 50 mc range where third mode crystals are used, the use of a high IF frequency like seven megacycles is very helpful in the production of the crystals as it limits the highest frequency crystal to 43 mc. The use of a 3.0 mc high IF would require the production of 47.0 mc crystals which is obviously somewhat more difficult when produced to the same activity as the 43 mc crystal. Consequently we see that the choice of the high IF frequency can have an important effect on the production of the mode or first oscillator crystal. However, do not draw the conclusion that it would, therefore, be wise to choose a rather high first IF frequency, as we will now consider some of the other factors mentioned above which enter into the choice of the most desirable operating frequency for the high IF amplifier.

We will consider a few of the typical and troublesome spurious always present wherever even one conversion is present in a superheterodyne. The first one will be the input frequency for the receiver which produces half the low IF amplifier frequency in the plate circuit of the second converter. Just for illustration, assume the low IF amplifier to be 455 kc and the high IF amplifier to be 6.0 mc; then with an off-frequency signal sufficient to produce 5.780 mc in the high IF amplifier we will have the second harmonic of the second converter output exactly on frequency for the high gain 455 kc low IF amplifier which follows this converter. Now the gain in the average low IF amplifier is approximately 200,000. In addition to the above situation, it must be remembered that any good converter is a very capable producer of harmonics since the tube used must operate in a region where the plate characteristic has appreciable curvature. With this set of conditions, it becomes evident that we face a serious problem when we have a 250 watt transmitter operating at a frequency of 200 to 240 kc (approximately one-half the low IF) below the desired or receiver frequency. Certainly, as a first remedy to this situation good selectivity in the high IF amplifier is the most obvious solution, as the selectivity of this amplifier prevents this off-frequency carrier from driving the second converter grid. Another method to prevent this off-frequency signal from producing appreciable drive at the second converter is to design for low level limiting in the high IF amplifier tube.

Another important consideration involved in the choice of a high IF frequency is the harmonics of the second converter for signals close to the desired or on-frequency signal. The harmonics of the IF frequency present in the plate circuit of the second converter can produce a whole series of spurious responses depending on the high IF frequency, the selectivity of the second converter input circuit, and the level at which limiting occurs in the high IF amplifier tube. The harmonics of the IF generated in the second converter are fed back to the input side of the converter through the plate to grid capacity of the tube and other stray capacities, and then beat with the oscillator injection frequency and with the incoming frequency to produce a whole series of spurious responses. To alleviate this situation it is desirable to choose the high IF frequency so that the first IF harmonic involved in this type of spurious falls near the center of the low IF pass band. This will then give the largest frequency interval before this harmonic gets outside of the low IF pass band so the selectivity of the high IF amplifier can attenuate the input to the second converter. Other means of alleviating trouble from this situation lie in the design of the low IF amplifier. These will not be covered here as we are going to confine ourselves to the front end of the receiver.

Where the first crystal is multiplied up, it becomes important to choose the high IF frequency in order to get sufficient protection from the rf amplifier so that the harmonics adjacent to the desired can be attenuated by the rf amplifier. Consider a typical case: suppose we are multiplying by twelve times in the first crystal oscillator; the high IF is 6.9 mc and the tuning range of the receiver is 152 mc to 174 mc. The first crystal frequencies will be from 12.09 to 13.925 mc. Let us take a look at the high end of the band -- say, 173.8 mc. At this operating frequency the 13th harmonic of the crystal is 180.806 mc. Assume an input signal one channel higher in frequency than the receiver is tuned to (173.860 mc), then the resultant frequency from the 13th harmonic beating with the incoming signal will produce a signal which is only 46.0 kc above the nominal high IF frequency. Such a condition is certain to produce a spurious on the adjacent channel which would be very hard to reduce to a tolerable level. In this case a change in high IF frequency is the logical solution. The case cited above would cause adjacent channel interference whether we have 40 kc or 60 kc channels, since the low IF pass band in either case is ±15 kc. It will also result in alternate channel interference.

For protection in regard to the second image, it is the same story as it was in the cases cited above. The only solution is adequate high IF selectivity. The second image frequency is, of course, decided by the frequency of the low IF amplifier. It is always located at twice the low IF frequency above or below the high IF depending on whether the second oscillator injection is above or below the high IF operating frequency. Therefore, one must depend on the selectivity of the high IF amplifier in order to avoid this spurious response. The rf amplifier can contribute some, but not a great deal, as shown in Fig. 3.

The basic selectivity of the high IF amplifier itself is closely tied up with its operating frequency. This occurs because of two important factors: we can get more coil performance ("Q") at the lower IF frequencies due to the characteristics of iron dust cores. The other factor is sim-

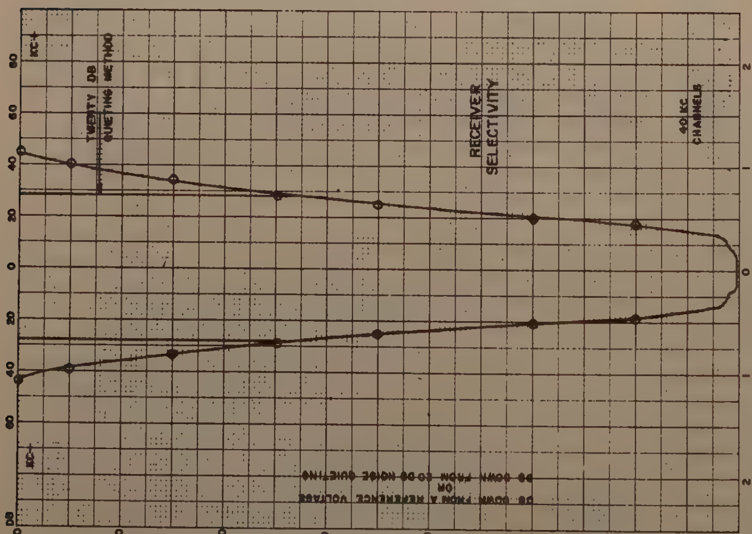

Fig. 2

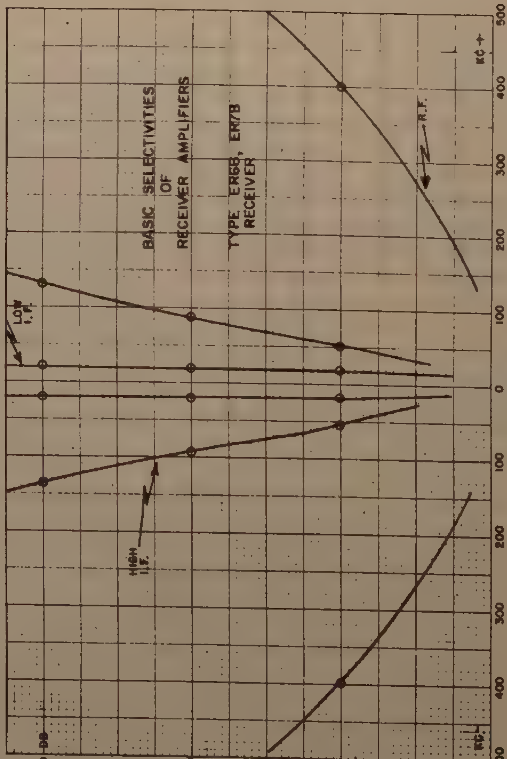

Fig. 3

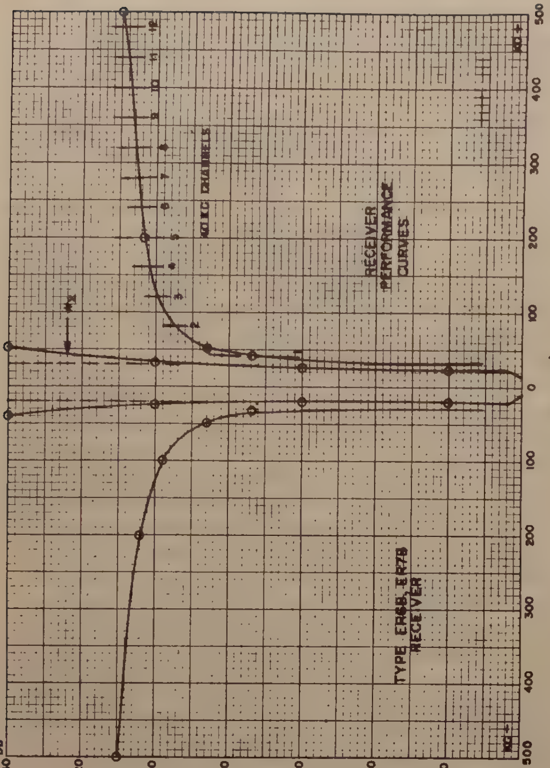

Fig. 4

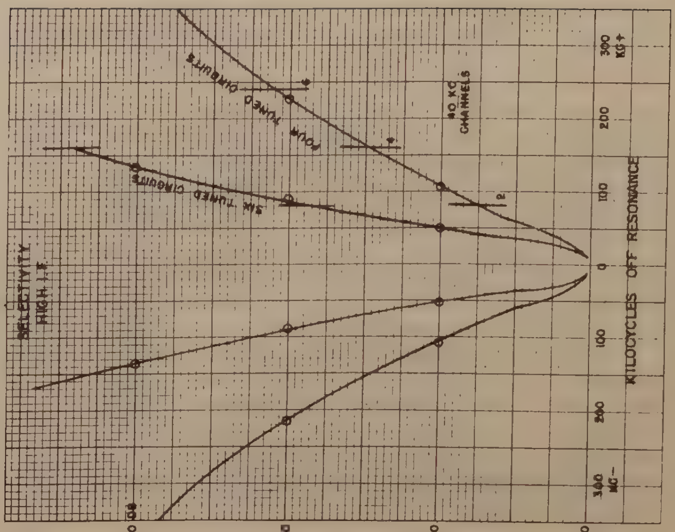

Fig. 5

ply the variation of selectivity with operating frequency on a straight percentage basis. That is, 120 kc is a long way off frequency for a 6 mc high IF amplifier, but would be a rather small percentage off frequency in the case of an 18 or 20 mc high IF amplifier.

From the problems cited above, which are related to the choice of the high IF frequency, we noted that many could not be solved except by adequate high IF selectivity. The question then arises as to how much selectivity should be designed into a high IF amplifier or whether the more selectivity the better should be the criterion. In general, the latter is true, providing the bandpass is adequate to pass the modulation. Let us now consider what advantages besides those already mentioned will occur with the higher order of selectivity in the high IF amplifier. One of these advantages occurs in intermodulation. If the high IF selectivity is only moderate, then the high IF amplifier tube always contributes to the intermodulation produced in preceding tubes. In order to avoid having the high IF amplifier contribute to the intermodulation already present in the rf amplifier, it is necessary that the selectivity of the first high IF transformer have an attenuation of approximately 10-1 for twice the channel spacing. If this is not the case, then the high IF amplifier tube will contribute another 6 db of degradation under average operating conditions.

The manner in which the high IF amplifier selectivity contributes to the over-all performance is easily shown by looking at the desensitization curves or the two-signal performance curves of the receiver. In Fig. 4 is shown the two-signal performance curve which applies to the receiver having the selectivities shown in Fig. 3.

Just a few words about the significance of this illustration. The inside curve is the conventional 20 db quieting curve. The next curve (#2) is the basic selectivity of all the tuned circuits of the receiver without any limiting taking place in the entire receiver. Note how this #2 curve lays quite well on the 20 db quieting curve, until limiting takes place somewhere in between or preceding the selective elements of the receiver, and then the two curves depart. This departure is typical of any receiver manufactured today and starts when limiting occurs, usually at the second converter or the high IF amplifier. This outer or true selectivity curve you will note is bell-shaped as we get into the higher attenuation. Certainly any true selectivity curve must have this kind of a shape since the over-all selectivity is made up of individual circuits, each of which has a bell shape. Of course, we do not have an infinite number of tuned circuits so the over-all result, if it is to be correct, must have a bell shape. The other curve is a standard two-signal performance curve taken on a signal-to-noise-ratio basis. The desired signal is at zero discriminator and is of such a strength as to produce a 12 db signal-to-noise ratio with no interfering signal present. Modulation is 10 kc at 1,000 cycles. The interfering signal is then introduced and modulated at 400 cycles 10 kc deviation for wide band receivers. To get the data for the two signal curves, the interfering signal is set off frequency and then increased in strength until the signal-to-noise ratio of the desired or weak signal is reduced from 12 db to 6 db, or from 25% to 50% distortion (with the squelch set at critical). This curve then contains much more information than either of the other curves, since it predicts exact performance from the side walls of the basic selectivity curve on out as far as you want to go.

With a method of measurement which is capable of producing such data, we can readily dispel any and all mystery about the contribution of the front end of the receiver to the over-all performance. For instance, we can vary the high IF selectivity, the gain and the distribution of this selectivity and, using the same low IF and rf amplifier, observe the results obtained. When this experiment is performed, we find that from 45 kc out to 500 kc the slope of the two-signal performance curve is determined largely by the high IF amplifier selectivity. After this region has been passed, desensitization is occurring in the high IF amplifier. The two-signal curve would become flat except for the fact that the rf selectivity is contributing and determining the skirt slope, and finally, after this region, the skirt slope is determined by the selectivity in front of the first grid, or by the selectivity of the preselector (antenna transformer).

Fig. 5 shows typical single stage high IF amplifier selectivity curves. The outer curve shows the selectivity of a high IF amplifier stage using two double-tuned transformers or four tuned circuits. The inner curve shows the selectivity of a high IF amplifier using two triple-tuned transformers or a total of six tuned circuits. Note that the difference in selectivity is 21.0 db at channel #2 and 38.0 db at channel #4. Fig. 6 shows the effect on the two-signal performance curves of using each of these high IF amplifiers in conjunction with the same rf and low IF amplifier. Note how the two-signal performance improves with the more selective high IF amplifier. Selectivity in this region of the receiver improves reception on many channels besides improving reception slightly on adjacent channels. Only one side of the two-signal performance curve is shown; the other side showed a very similar improvement.

The average improvement over the frequency spectrum shown in Fig. 6 is 7.0 db. These improvements in performance apply to both high band (150-174 mc) or low band receivers (25-50 mc) and extend out to improve performance on many more channels than shown in Fig. 6.

Fig. 7 shows the effect of changing the gain in the high IF amplifier of a particular receiver. The high IF amplifier gain was increased by 9.5 db and the two-signal performance, starting from channel #2, decreased by approximately 2.0 db. By increasing the gain of the high IF amplifier on various receivers, it was found that the results obtained varied so widely that one could not make a definite prediction which would apply to all re-

ceivers. On one of the receivers in which the gain was increased 6.0 db by merely increasing the screen voltage of the high IF amplifier tube, the reverse was true for the high frequency side of the two-signal performance curve; whereas the low frequency side showed essentially the same performance.

An inspection of a two-signal performance characteristic previously shown in Fig. 4 raises a question in regard to the value of performance a receiver should attain when used on a common tower with another system in the same band. This would, of course, depend on the vertical separation of antennas and the frequency separation, but should equal or exceed transmitter noise performance. From data currently available on 250 watt transmitters in the 25 to 50 mc mobile communication field, the receivers should be capable of 97 db on adjacent channels, 105 db on the 4th channel, and 129 db on the 10th channel, in order to provide the maximum useful communication range made possible by the lower noise level of recent transmitters.

The rf Amplifier

The principal considerations in the design of the rf amplifier are in general very similar to the high IF amplifier, if we omit the signal-to-noise-ratio problem encountered in the first amplifier tube. We have the same problems at the first converter as we do at the second converter with respect to the spurious responses. At half the high IF frequency below the desired signal the first converter produces a spurious just as the second converter did. There is essentially no way to avoid this spurious and it can always be reduced either by using a higher high IF frequency or by increasing the rf selectivity. Similar considerations apply to the high IF harmonics as were mentioned in conjunction with the high IF amplifier. I will, therefore, pass over these and look at some of the other aspects of the rf amplifier.

The total selectivity required in the rf amplifier is largely determined by the image ratio and by the spurious response ratio. For such spurious as the one occurring at one-half the high IF amplifier frequency from the desired signal and the image, there is little more that can be done except to provide adequate selectivity, since the many image rejection circuits which have been devised (not requiring additional tuned circuits) are difficult to maintain in balance when the front-end frequency is changed by field personnel.

Then there is a question as to how many db down from receiver sensitivity are required in a good communications receiver for this type of spurious and those present at the second converter. This will depend on how many spurious are present after the most judicious choice of high IF frequency, proximity of receivers and transmitters, and, of course, the power output of the transmitters in the communications band and the band immediately below the communications band. As for the communications band transmitters, we can assume 250 watt transmitters, (+24 db) receiver squelch opening sensitivity set to 0.2 μv = (-152 db down from 1.0 watt) and a space attenuation of 60 db due to vertical spacing or horizontal distance between antennas. Under these conditions the image and spurious ought to be 152 + 24 - 60, or 116 db, for adequate protection. Some receivers on the market exceed this for all major types of spurious, such as the image, but may have only one spurious which gets down to 85 db at one end of the band and therefore are rated at the lower value.

In the rf amplifier it is extremely important to have as much of the total rf selectivity in front of the first grid as is possible. The limitation here comes in sensitivity due to the loss incurred by each tuned circuit. There are many advantages in this kind of a design and I will illustrate two typical cases, namely, desensitization and intermodulation. Fig. 8 shows one half of the selectivity curve of a single tuned iron core antenna transformer (the lower curve) and also the selectivity of a double trimmer tuned antenna transformer (upper curve). Note that the lower curve "B" accepts a much higher level of carrier for a transmitter 1.0 and 2.0 mc removed from the receiver frequency. The difference is actually 16 db at 1.0 mc and 30 db at 2.0 mc. Assuming the lower curve and with a 250 watt transmitter one-half mile away and one-half megacycle off frequency, the first grid will normally receive sufficient carrier to bias the rf amplifier grid to 4.0 volts, thereby desensitizing the first tube due to carrier alone. This situation would not exist if the input selectivity equaled that of the upper curve.

Let us now consider the advantages of high selectivity in the antenna transformer as regards intermodulation. Since intermodulation takes place in the first rf amplifier tube due to the nonlinearity in the plate circuit of the amplifier tube, we must prevent the signals involved in intermodulation from reaching the first grid if we are going to avoid this difficulty. No antenna transformer by itself is sufficiently selective to enter the intermodulation picture on adjacent channel stations. However, in many of the cases the intermodulation occurs due to stations ten or more channels away from the frequency to which the receiver is tuned. A glance at Fig. 8 shows that the double-tuned preselector will offer an attenuation of 12 db to one of the signals involved in producing the intermodulation, whereas the attenuation of the single-tuned transformer is negligible As the number of stations on the air increases, this type of interference will be more prevalent. We must, however, do something to improve the intermodulation situation for those stations which lie in closer than one-half a megacycle, and we can accomplish this if we take advantage of the adaptability of the double-tuned preselector to the use of quartz crystals as filter elements.

Due to the sharp resonance of these crystals, they can be used as shorting elements in conjunction with tuned circuits. A typical preselector circuit equipped with crystals is shown in Fig. 9. If intermodulation is present from a higher frequency adjacent and alternate channels stations,

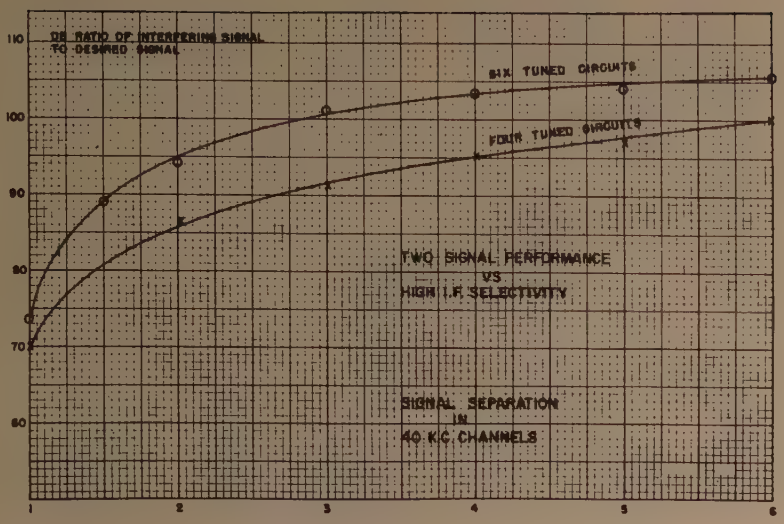

Fig. 6

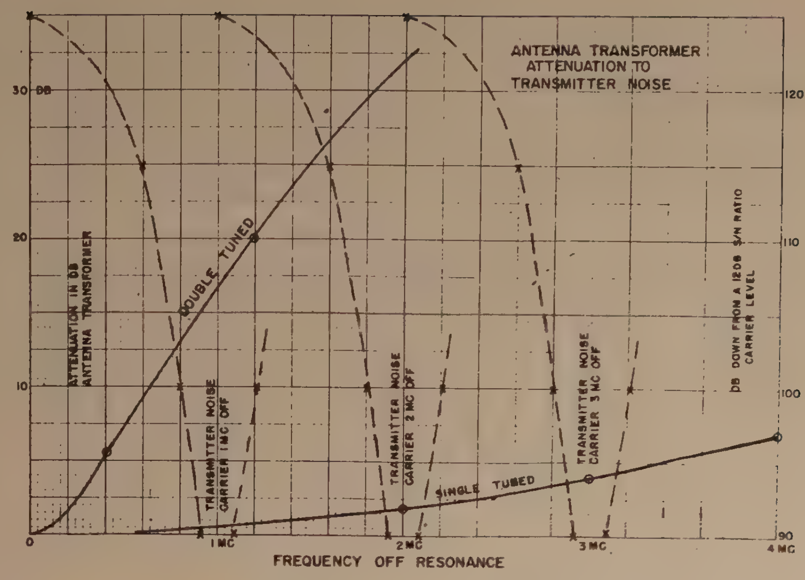

Fig. 8

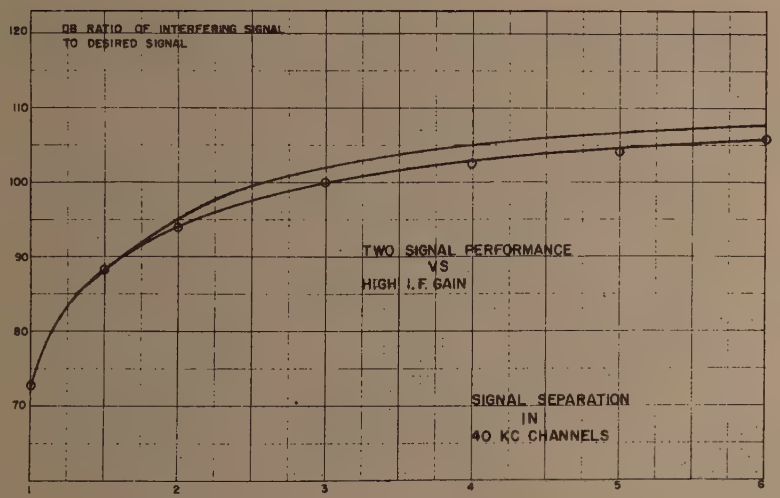

Fig. 7

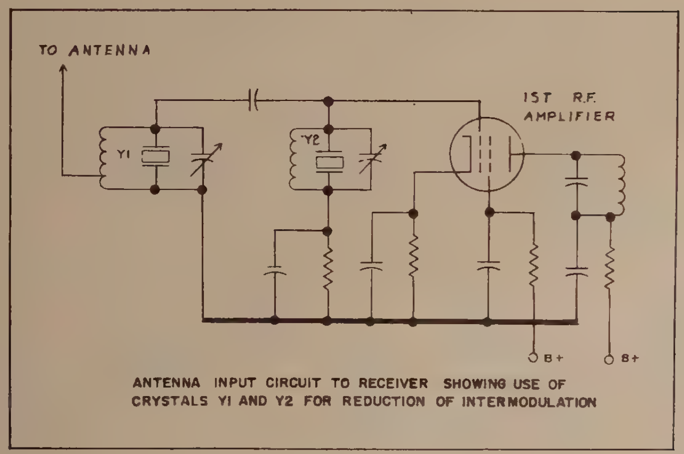

Fig. 9

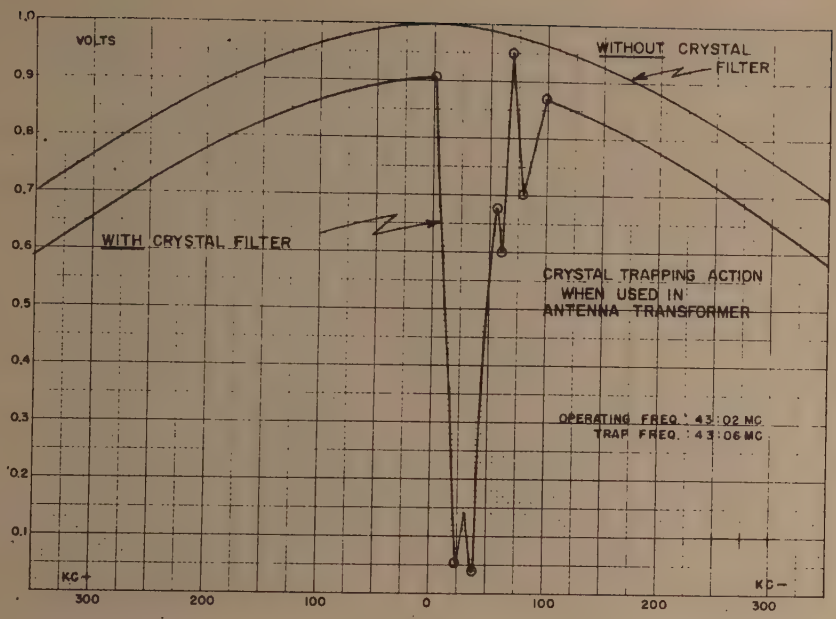

Fig. 10

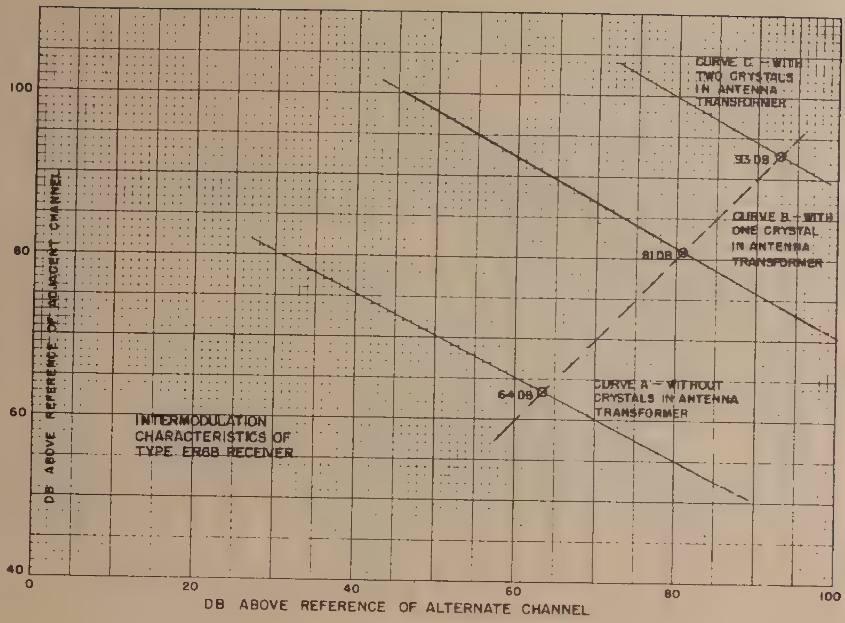

Fig. 11

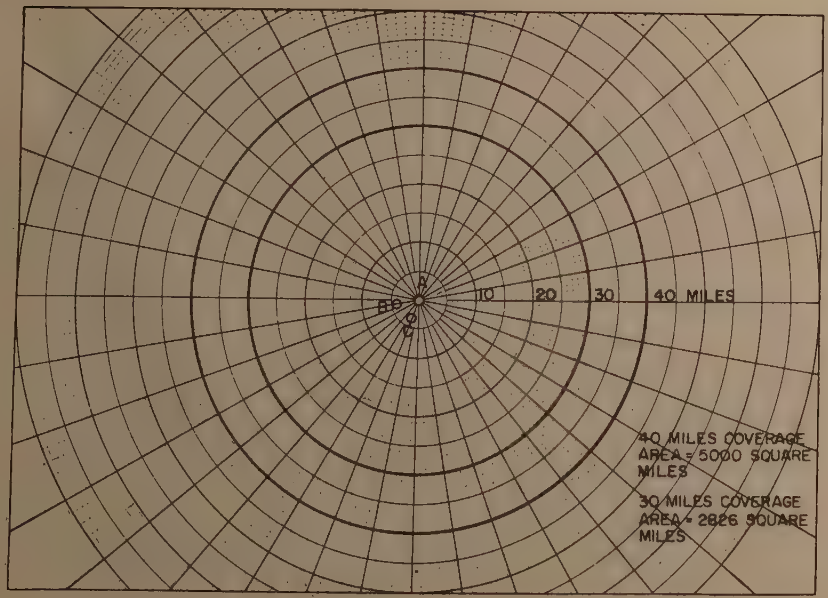

Fig. 12

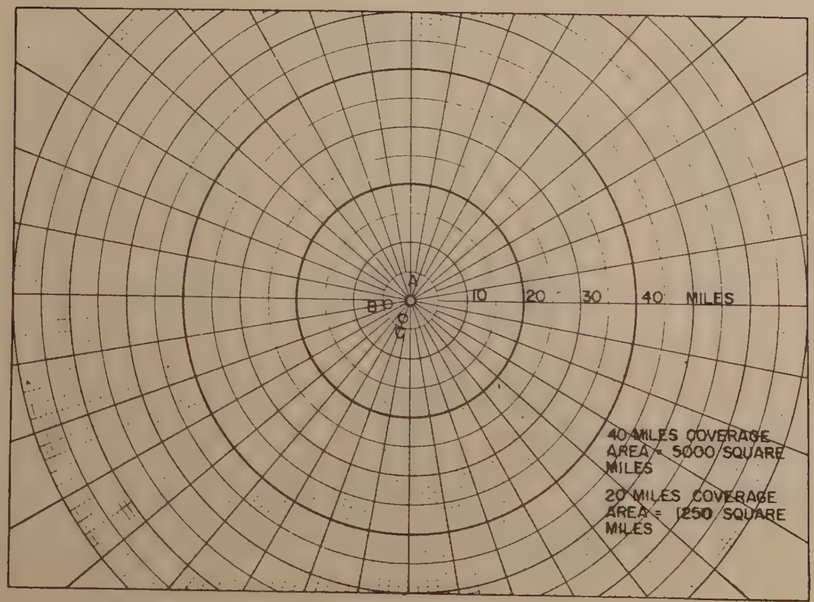

Fig. 13

quartz crystals operating on mode frequencies can be connected across the tuned preselector circuits as shown -- one for each interfering signal -- and at crystal resonance the equivalent resistance of each crystal will drop to a value of something like 20 ohms. Since the tuned circuits have an impedance of 5,000 to 100,000 ohms, even a 50 ohm loading across the tuned circuit will reduce transmission through the preselector to a small value, thereby reducing the undesired carriers and avoiding the intermodulation effects. In most cases it is only necessary to use a single crystal and in this case it is generally advisable to place the crystal across the circuit connected to the grid of the tube. Also it is desirable to trap the frequency which produces the second harmonic in the plate circuit of the rf amplifier tube.

Fig. 10 shows a typical resonance curve of a double-tuned antenna transformer equipped with a crystal. The top curve "A" shows the rf selectivity without the crystal. Curve "B" shows the effect of adding the crystal in the grid coil of this transformer. Note that in less than 25 kc the crystal has provided an attenuation of nine to one and also that there was a loss in gain due to the crystal of 10%. The loss of gain can be avoided by ordering a crystal for filter or trap application. The curve shown was taken from a crystal made for oscillator usage. After the first sharp attenuation, the crystal has spurious responses which occur only at frequencies higher than the frequency to which the crystal has been ground. If the desired signal is lower in frequency, then these spurious responses will do no harm and may be helpful in trapping the alternate channel carrier with the same crystal. When a lower frequency carrier is trapped by using a crystal, then a filter type of crystal must be obtained on which the spurious responses are known or have been removed by special processing of the crystal blank.

The quartz crystals have an advantage over cavities in that they have a much higher "Q," produce less loss on the desired signal and are temperature compensated. They need never be retuned since they are temperature compensated in the same order of accuracy as the associated crystal oscillator in the transmitter producing the interfering carrier.

Fig. 11 shows the typical intermodulation characteristics of a General Electric ER-6 or 7B receiver: curve "A" without crystals, curve "B" with one crystal and curve "C" with two crystals used on adjacent and alternate channels. The desired signal in this case was on 43.02 mc and there was no reduction in sensitivity on the desired frequency due to the presence of the two filter crystals which were higher in frequency.

An inspection of curve "B" shows that the addition of this particular crystal improved the intermodulation figure by 17 db. It is probable that the same crystal reduced both the adjacent and the alternate channel, as these curves were taken with the desired signal lower in frequency than the signals causing intermodulation. The same benefits can be derived with the use of the crystal in the antenna transformer for desensitization caused by a nearby transmitter, providing the desensitization is primarily due to carrier and not transmitter noise. With a third mode crystal operating at 43.02 mc, an improvement of 10 db was obtained in the adjacent 20 kc channel by the introduction of a single crystal across the secondary of the antenna transformer, with no reduction in receiver sensitivity on the desired signal.

We have now seen whereby the use of a higher order of selectivity in the high IF amplifier produces a receiver having better two-signal performance by as much as 7 db for more than twice the frequency spectrum shown in Fig. 6 for high-band or low-band receivers. Also, in the case of the low-band receiver, we have seen where the more selective antenna transformer reduced desensitization due to carrier and reduced the intermodulation by 12 db. Due to the double-tuned type of antenna transformer, a single front end crystal improved the intermodulation figure as much as 17 db. We are now in a position where these receiver front-end improvements must be translated into coverage in miles in order to fully realize what the db improvements mean in the system performance.

An improvement of 6 db in receiver performance will essentially double the free space system performance. Moreover, for the case of transmission over land of average terrain, a 12 db improvement in receiver performance will double the system coverage. This information is available from the General Electric slide rule signal calculator. With the use of this slide rule, Fig. 12 has been prepared which shows the increased coverage obtained due to the more selective high IF amplifier shown in Fig. 5. In this figure the inner circle shows the area of coverage of the receiver at "A" when station "B" is on the air, causing a 7.0 db desensitization in the receiver at "A." The outer circle shows the coverage for "A" when the 7 db of desensitization is not present. The area between the circles represents the increased coverage and is an increase of 76%. In conclusion, Fig. 13 shows the increased coverage resulting from the addition of a single crystal to the front end of the receiver for the case where intermodulation was limiting the receiver performance. This has increased the coverage area by 300% over what it was before this modification was made to the front end of the receiver. Certainly this represents a tremendous gain in coverage for the small cost of a crystal added to a standard receiver.

In a broader sense, let us summarize the foregoing in terms of front-end performance: increased performance in the front end of the receiver makes that receiver approach more nearly the ideal receiver. We should know, without making any measurements, that this must provide superior performance. There can only be a question of how much. How much has been shown in db in Figs. 6 and 11 and in system coverage in Fig. 13.

A SQUELCH SYSTEM CONTROLLED BY SIGNAL-TO-NOISE RATIO

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Cedar Rapids, Iowa

Summary

Since the quality of communications is a function of signal to noise ratio, it follows that a squelch system will perform its intended function more proficiently if it operates directly as a function of this ratio. The threshold of operation of the commonly used carrier-operated system varies widely with changes in ambient noise conditions and receiver gain. This squelch system overcomes these objections to the carrier-operated squelch and may also prove useful for suppressed carrier systems. Formulas applicable to circuit operation and practical circuitry which will provide consistent operation for signal plus noise to noise ratios as low as 2 db are given. Results of field tests are also included.

Introduction

Practically all communication receivers operating in the VHF and UHF regions utilize squelch systems. The purpose of the squelch is to quiet the noise output of the receiver when no signal is present in order to reduce operator aural fatigue. It may also operate a relay in order to energize a transmitter for automatic retransmission purposes.

The squelch circuits must be capable of operating on very weak signals or useful transmissions may be lost due to the inability of the squelch to detect the presence of the signal. On the other hand, if the squelch is too sensitive it will operate due to the presence of noise alone which is highly undesirable.

Objections to Presently Used Systems

Most of the squelch circuits in common usage operate from the increase in detector voltage caused by the presence of a received carrier signal as shown in Figs. 1 and 2. Unfortunately, an increase in noise at the detector will also cause an increase in the detector voltage. Thus, the carrier-operated type squelch circuit cannot distinquish between a weak carrier signal and noise.

If the operator has access to a squelch threshold control, the control may be set so that the squelch circuitry will operate at a level just slightly above the ambient noise level. So long as it is convenient and practical to set and reset the threshold control with changing conditions as required, this type of operation will give satisfactory results.

Unfortunately, it is never fully convenient for the operator to reset the control and in some cases it is not practical to install the control. Particularly in airborne installations where the operator may be the pilot, it is highly undesirable for him to have the additional chore of checking the setting of the threshold control during flight.

Even in ground installations, some communications may be lost if the operator allows the squelch threshold setting to become too insensitive. In remotely controlled ground installations, the circuitry required to provide remote squelch control adds further complication.

In one recently designed ground installation providing remote selection of ten preset channels, it was necessary to provide ten remote squelch controls (one for each channel) so that the threshold level could be set for each channel. This was necessary due to the change in gain of the receiver over the frequency range. Fig. 3 shows values of input signal required at different channel frequencies to open the squelch circuit on a typical UHF receiver. It thus becomes apparent that carrier-operated squelch circuits create problems which are not insignificant.

The reasons for the above objections to a carrier-operated squelch may be summarized as follows:

1. The threshold level of the squelch circuit must be set very close to the ambient noise level.

2. Since the presence of a carrier or an increase in noise both result in an increase in the voltage which controls the squelch, no distinction can be made between carrier or noise.

3. The ambient noise level may exceed the squelch threshold level when ambient noise conditions change or when the receiver gain changes. The receiver gain will definitely change with changes in channel frequency or line voltage.

Circuit Design of Signal to Noise Ratio Control

The problem thus resolves itself into combating changes in ambient noise level and receiver gain or devising a different type of squelch circuit which eliminates the above problems. At UHF and VHF frequencies, the ambient noise level is not usually the significant factor; however, in unique cases where it is a problem, it is difficult if not impossible to control. It is also difficult if not impossible to build a receiver which gives constant gain over wide ranges of frequency and line

voltage. This leaves only the third alternative which is a different type of squelch circuit.

Since the quality of communication is a function of signal to noise ratio, it follows that a squelch system will perform its intended function more proficiently if it operates directly as a function of this ratio. In order to provide this type of operation, a voltage proportional to the signal plus noise function and a voltage proportional to the noise function must be derived.

Due to the relatively wide IF pass bands which are provided in VHF and UHF receivers for frequency stability reasons, it is possible to divide the audio output into two spectrums with appropriate filters as shown in the block diagram of Fig. 4. The output of the low pass filter which contains the usual audio spectrum of approximately 300 to 4000 cps will be proportional to the audio signal plus noise power which exists in the filter pass band. The output of the high pass filter which rejects the audio signal will be proportional to only the noise power which exists in the filter pass band. Since the ratio of the noise power existing in the low pass band to that existing in the high pass band is a constant for a given set of filter characteristics, it is possible to manipulate the outputs of the two filters to provide an output which is a function of the signal plus noise to noise ratio for a given level of squelch operation. The circuit operation is explained as follows:

Referring to Fig. 4, the output of rectifier "A" causes current I_1 to flow and develops a voltage across resistor R_2 which is proportional to the low frequency noise plus the audio signal. The output of rectifier "B" causes current I_2 to flow through R_2 in opposition to I_1. The voltage developed across R_2 by I_2 is proportional to the high frequency noise.

It may be shown as follows that true signal plus noise to noise operation will be obtained providing the circuit which controls the squelch relay is adjusted so that relay operation occurs when E_o is zero and maintains the relay in an operated position as E_o increases in the negative direction.

1. Let E_{nhf} = voltage developed across R_2 by the high frequency noise.
   Let E_{nlf} = voltage developed across R_2 by the low frequency noise when no audio signal is present.
   Then $\frac{Enhf}{Enlf}$ = K (a constant) as has been previously stated.

2. Let E_o = voltage output as indicated on figure 4.

3. Let $E_{nlf} + E_s$ = the voltage developed across R_2 by a signal made up of audio and low frequency noise.

4. Due to the opposite polarities indicated on the block diagram, it is evident that:

$$E_o = E_{nhf} - (E_{nlf} + E_s)$$

From 1. above:

$$E_{nhf} = K(E_{nlf})$$

$$E_o = K(E_{nlf}) - E_{nlf} - E_s$$

$$\frac{E_s + E_{nlf}}{E_{nlf}} = K - \frac{E_o}{E_{nlf}}$$

If operation occurs when $E_o = 0$, the above equation becomes:

$$\frac{E_s + E_{nlf}}{E_{nlf}} = K$$

at the time operation occurs.

Thus, operation occurs for a constant value of signal plus noise to noise ratio. Since K is equal to the ratio of the voltages developed across R_3 and R_4 when no audio signal is present, K may be set to the desired value by measuring these voltages and adjusting R_1. It is also evident that K must be greater than 1 to prevent operation due to noise alone.

The output voltage E_o is applied to the grid of V_1 of the first relay control tube as shown in Fig. 4.

<u>Relay Control Circuitry</u>

The relay control circuitry may be briefly explained as follows: Referring to Fig. 4, assume E_o is positive and V_1 is conducting. The voltage drop across R_5 due to the plate current of V_1 places a bias on V_2; no plate current flows in V_2 and the relay is open.

Resistor R_7 places the correct bias on V_1 so that operation will occur when E_o decreases from a positive value to approximately zero. As E_o approaches zero, the plate current of V_1 decreases and the voltage drop across R_5 decreases which lowers the bias on V_2. As V_2 begins to conduct, its plate current flows through R_7 which also increases the bias on V_1 tending to cut off its plate current. This effect acts in addition to the effect caused by decreasing E_o. Thus a regenerative action occurs near the operating point and gives a very desirable snap-in action for relay operation. The size of R_7 is limited by the allowable ratio of "squelch on" to "squelch off" control voltage.

If it is desirable to switch to carrier-controlled operation of the squelch circuitry, a voltage derived from the detector circuit is applied to the grid of V_1 for normal carrier-controlled operation. Thus, it is convenient to switch from one type of operation to the other.

In the original development of this circuit, the filters consisted of units giving very high

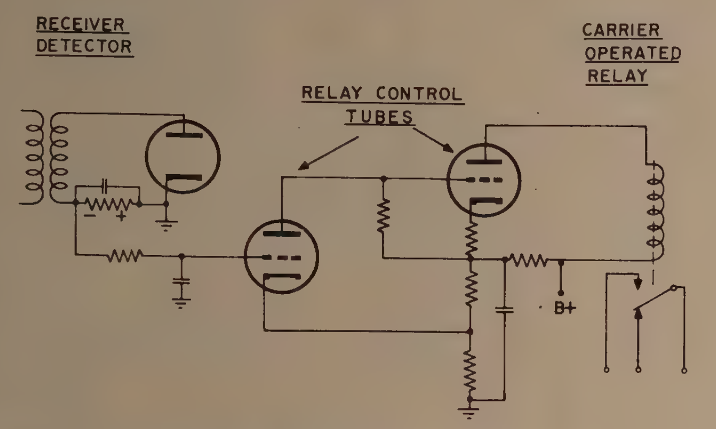


FIGURE I. TYPICAL CARRIER OPERATED SQUELCH CIRCUIT USING RELAY CONTROL

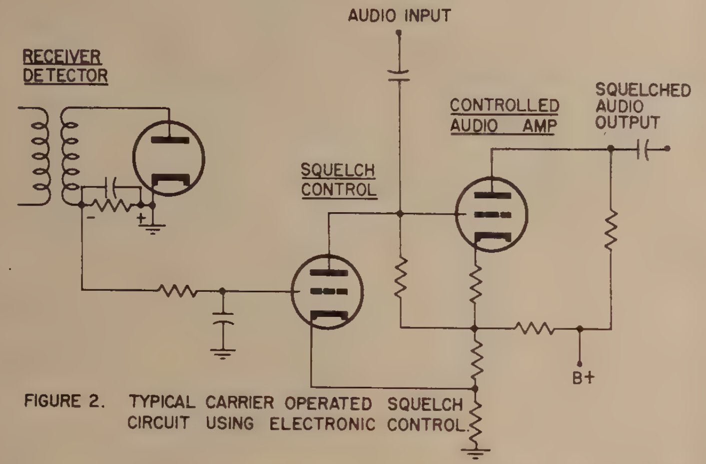


FIGURE 2. TYPICAL CARRIER OPERATED SQUELCH CIRCUIT USING ELECTRONIC CONTROL.

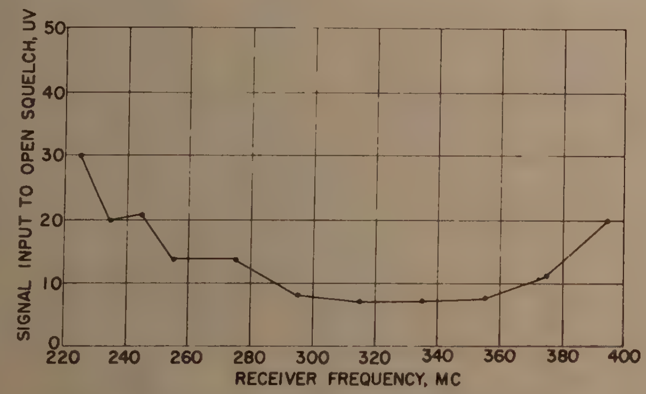
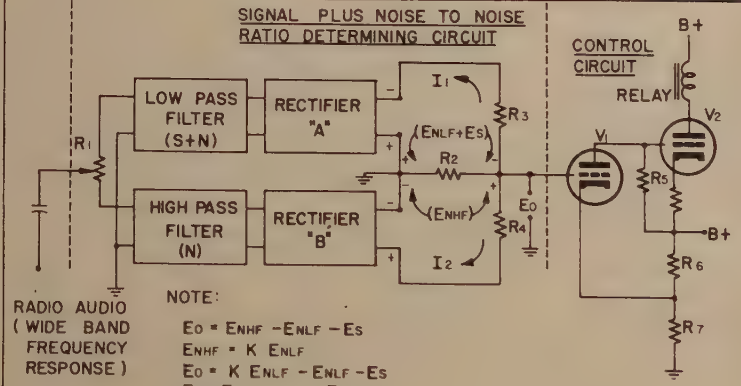


FIGURE 3. CARRIER OPERATED SQUELCH OPENING LEVEL VS. FREQUENCY FOR A TYPICAL UHF RECEIVER.



NOTE:

$E_O = E_{NHF} - E_{NLF} - E_S$

$E_{NHF} = K\ E_{NLF}$

$E_O = K\ E_{NLF} - E_{NLF} - E_S$

$\dfrac{E_S + E_{NLF}}{E_{NLF}} = K - \dfrac{E_O}{E_{NLF}}$

WHEN $E_O = 0$, $\dfrac{E_S + E_{NLF}}{E_{NLF}} = K$

FIGURE 4. BLOCK DIAGRAM OF SIGNAL PLUS NOISE TO NOISE SQUELCH CIRCUIT.

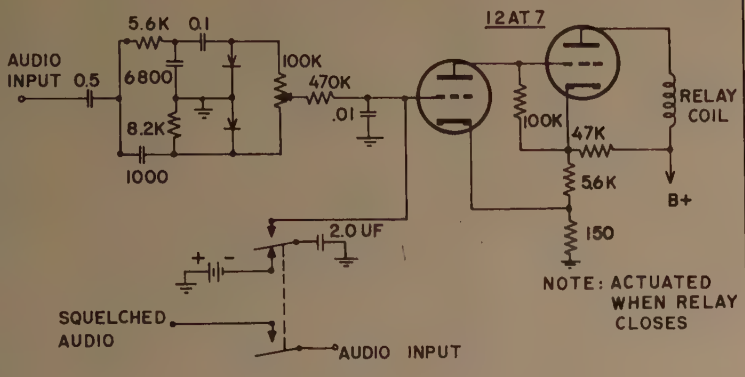


FIGURE 5. PRACTICAL CIRCUIT OF SIGNAL PLUS NOISE TO NOISE SQUELCH (R-C FILTERS).

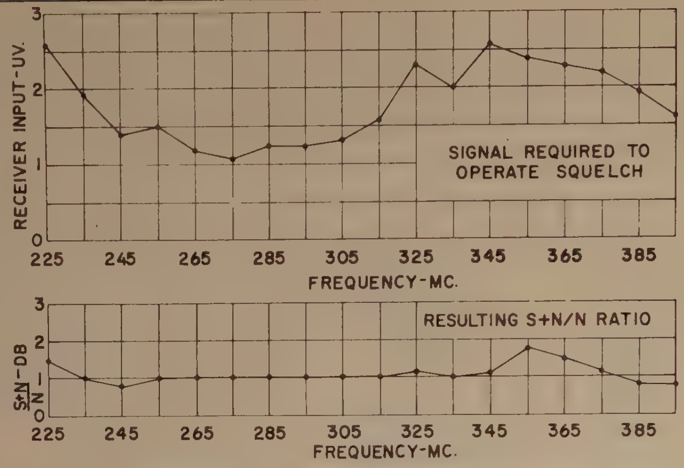


FIGURE 6. PERFORMANCE OF SIGNAL PLUS NOISE TO NOISE SQUELCH (R-C FILTERS)

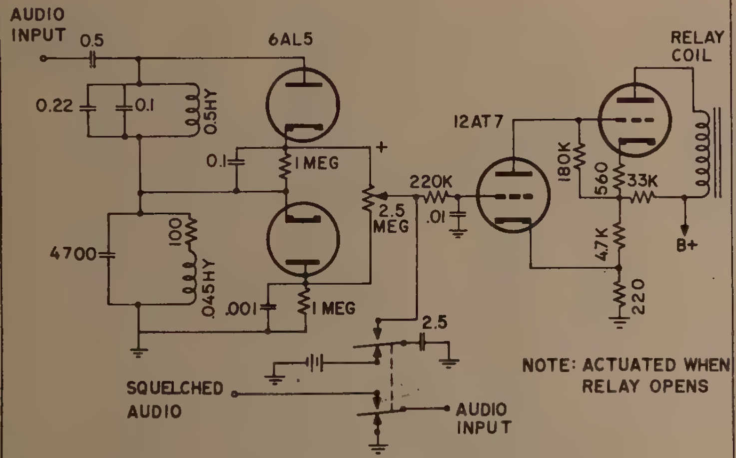
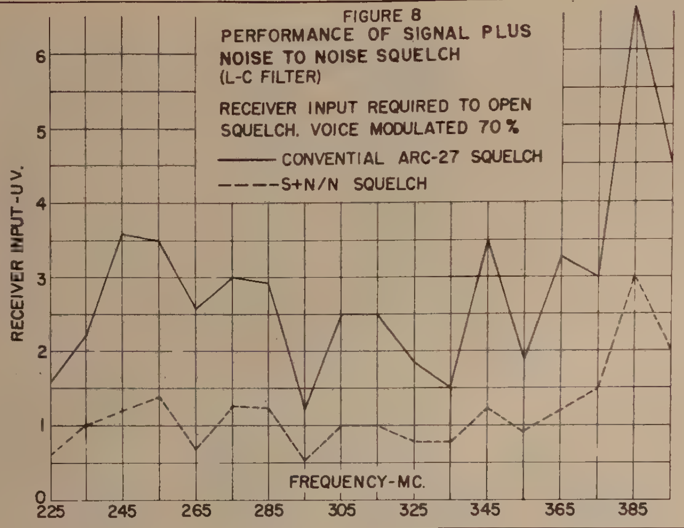


FIGURE 7. PRACTICAL CIRCUIT OF SIGNAL PLUS NOISE TO NOISE SQUELCH (L-C FILTERS)



rejection to frequencies outside the respective pass bands. To conserve space and reduce cost, the quality of the filters has been reduced to a single R-C section for each filter while maintaining operation on S+N/N ratios as low as 2 db.

Reliable operation depends upon using circuitry which will give a positive ON-OFF action for small changes in the control voltage. Thus, the gain available in the two control tubes should be as high as possible. The magnitude of the change in the control voltage which is available for operation at low values of S+N/N is determined by the magnitude of the audio voltage driving the S+N/N determining circuitry and by the losses in the filters and the resistive combining network.

One form of a practical circuit is shown in Fig. 5. The filters consist of single R-C sections and germanium or silicon diodes are used as rectifiers. Two sets of contacts are used on the control relay. One set controls the audio and the other connects an additional two microfarad condenser to the grid of the first control tube when the relay closes. This provides a delay on release without adding a delay to the attack time. Fig. 6 illustrates the results obtained with this circuit. The squelch opening level for this particular set-up was considerably less than 2 db S+N/N across the band.

Another version of a practical circuit is shown in figure 7. The filters consist of tuned L-C sections. The low frequency filter is resonant at 400 cps and the high frequency filter is resonant at 10,000 cps.

The circuit shown in Fig. 7 was used in conjunction with an ARC-27 multi-frequency UHF receiver by the Naval Air Test Center at Patuxent to evaluate the advantages obtained over the standard carrier-operated squelch circuit. The results are shown in Fig. 8. The data indicates that from 6 to 11 db more receiver gain may be used with this type of squelch.

Problems Encountered

It should be noted that the signal plus noise to noise circuitry by definition results in voice controlled operation. This action creates further problems and limits the usefulness of the circuitry in some respects.

In voice communication systems the attack and release time constants must be considered. Obviously the shortest attack time possible is desirable so that the first word or syllable is not lost. To date, our experience indicates that the attack time should be held to 6 milliseconds or less. The release time is more or less a matter of opinion at this time. If the release time is short, the relay will drop out between sentences or words. There is some indication that an advantage is to be gained for very weak or noisy signals by using a relatively short release time as the noise bursts between longer than normal pauses are eliminated. Thus the actual signal plus noise to noise ratio integrated over a period of several sentences is improved since the noise bursts have been removed. In listening tests conducted to date on systems using a short release time, we have had two reactions. Some people believe they benefit from the noise burst elimination and others object to the intermittent action of the squelch. In tests run by the Naval Air Test Center at Patuxent River, Maryland, it was indicated that a release time of about two seconds was desirable as the operator was not aware of any difference in operating effects between the usual carrier operated squelch and the signal to noise ratio squelch.

Recent circuit developments have shown that it is possible to combine the S+N/N control function with carrier control. This provides an inherent change in the mode of operation at a predetermined S+N/N ratio. Thus, at very low S+N/N ratios, which cannot be properly handled by carrier operation, voice controlled operation is available. At higher S+N/N ratios, carrier controlled operation takes over. Since a large percentage of most communications takes place at relatively high S+N/N ratios, a great portion of the objection to voice controlled operation may be eliminated.

It is also possible that the S+N/N squelch may find application in suppressed-carrier systems which cannot utilize a carrier-operated squelch.

Acknowledgment

The author wishes to acknowledge the kind assistance of Mr. J. W. Plummer of the Naval Air Test Center and Mr. C. D. Fedde of Collins Radio Company.

VEHICULAR RADIO STATION INSPECTIONS

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Thank you for asking me to appear before you and speak on the subject of "Vehicular Radio Station Inspections". This is an interesting assignment for me since I have been pretty closely associated with inspectional work for many years.

Briefly, the purpose of a radio station inspection is to determine whether the station is properly installed and is operated according to the terms of its Construction Permit or License, whether the proper grade of operators are employed, whether they use appropriate procedures and maintain the required station records. Also, the tower lighting conditions at stations with high towers are checked. This is for the purpose of assuring that the station does not maintain a hazard to air navigation, is making the best possible contribution in the public interest, and is living up to the obligations assumed by the owner under the license which the Commission granted him.

Inspecting engineers often listen to the station, checking on its air activities, from radio equipped inspection cars, to observe to what extent the channel is free of interference and to get an overall picture of the station's effectiveness. These observations frequently result in recommendations looking toward improvements in a station's overall efficiency.

The Commission's engineers render all possible assistance to station owners at the time of the station inspection, carrying out their instructions which read about as follows:

> "While it is the duty of the engineer to discover and report all deficiencies, discrepancies and violations, it is also his duty to assist the station licensee to avoid such conditions by advising concerning matters which should be corrected before they become serious. To this end, engineers should discuss with the licensee or his representatives, all unsatisfactory conditions or violations and should render, within limits and when requested, such technical advice as he may be able to give."

You will find that our engineers are men of considerable experience in various forms of radio communication. Numerically their number is not great because although the number of radio stations requiring inspection has tripled and quadrupled during the last few years, our appropriations have not kept pace and we are operating with a relatively small staff. In the main therefore, we are unable to make the frequent inspections which we once made and most inspections are made on a sampling basis. For example, at one time all radio equipped aircraft were required to be inspected at least once during their license period. That is, once every two years for scheduled aircraft and annually for itinerant aircraft, as well as immediately following a modification of station license. Today these inspections are made when an engineer visits an airport and makes an inspection of the ground radio facilities. Then the radio equipment of a few aircraft on the field, selected at random, are inspected.

Similar arrangements are made in connection with the inspection of radio equipped fleets. If a given fleet had twenty vehicular stations and used three different types of transmitters our engineer would probably sample inspect one or more cars of each typical installation.

Inspection offices of the Commission are maintained at thirty points throughout the United States, in Alaska, Hawaii and Puerto Rico. Each office has a definite area of responsibility. In order to streamline inspection trips as much as possible, some states are divided almost equally between two districts. For example, the State of Kentucky is divided between our offices in Chicago and Detroit, while the State of Iowa is divided between the Chicago and Kansas City offices. County lines are used in all cases but one to provide clearly understood lines of demarcation.

With full information at hand regarding stations in their district, engineers plan their inspectional trips in order to cover the greatest number of stations on the trip which our budget can afford. Newly installed stations, often with the associated vehicular fleets, are thus scheduled for early inspection, sometimes within weeks of their installation.

The time and date of our inspector's arrival is not made known because typical op-

eration and not "window dressing" is what the inspector will be looking for.

Generally, while on an inspection trip an engineer will inspect several stations of each class. He may go from a small police station having only one vehicle to a large metropolitan installation with more than one hundred and then may make a very complete review of the 50 kw broadcast station in the same or adjacent community. Later he may inspect stations in any of the many new services which have recently come into being.

In order to make a complete, factual and objective review of the station, its installation and operations, the engineer is conversant with the rules governing each of the services. He carries with him copies of the Rules, Commission Public Notices, and various forms which he will, on occasion, fill out to advise the station owner, in writing, that a discrepancy was discovered which was not corrected at the time of the inspection. These discrepancy notices require prompt answering to the Engineer in Charge with a description of the reasons for the non-compliance and the actions taken to prevent recurrence or continuation of the discrepancy. If the discrepancy can be corrected during an inspection no citation is issued, while if something is noticed during an inspection which may lead to a discrepancy at a later date, such as a tendency on the part of the equipment or operating habits toward an unsatisfactory condition, an Advisory Notice is issued by the engineer, calling attention to this fact.

Rather frequently engineers find discrepancies in vehicular associated installations which are the result of thoughtlessness or lack of knowledge on the part of the station licensee. Included, are failure to post the station license or identification card, failure to obtain transmitter measurements, failure to observe proper identification procedures or failure to maintain station records, where these are required.

Our records show that in some cases the station owner was properly informed of these requirements but has neglected to carry them out. The reasons given by licensees for failure to do these and other necessary things are varied and interesting. Occasionally, a licensee receiving a citation notice has failed to read or answer it. Later, when requested to furnish an explanation he has stated that he posted the citation notice near the transmitter thinking it was an extension of his station license. In other cases, he was not properly informed when the station was installed; and right here I think would be a good time to point out the great service which the installing technician is in a position to render the purchaser of radio equipment. In addition to giving him verbal instructions, it would appear that a written check-off sheet could be left telling him what to do and when. Or that, if possible, reminders be mailed to the licensee by the technician so that the station licensee would not overlook important details, not the least of which has been disclosed by Commission records to be the recurrent need to apply for renewal of his station license. Oftentimes too, we find that a station has been sold to another person and that the purchaser has not made an application for a new station license but continues the operation of the station, illegally, under the license granted to the former owner.

Our inspecting engineers are proud of their record of accomplishment in assisting station owners by affording advice, as requested, and offering suggestions for the improvement of service rendered by the stations.

This inspection work has been going on since July 1911. Historically, vehicular communication began further back than many of us realize. It is recorded that in 1885 Edison, with the assistance of Gillilaud, Phelps and Smith, developed a system of communication between railway stations and moving trains by means of induction and later in 1913 a system of communication using spark wireless apparatus was tested and found practical for communication with trains in motion.

The year 1918 saw great progress in the application of aircraft communications by radiotelephony and radiotelegraphy and in the following year successful transatlantic flights of Alcock and Brown of the American NC4 and of the British dirigible R34 focused attention upon the use of radio for aviation purposes, including its outstanding value in aerial navigation.

Time does not permit me to point out, by illustration, many of the services which our engineers have offered during an inspection of a station, but I might mention that there have been inspections during which a harried technician was wearily trying to complete an installation, had overlooked an important technical point and was unable to achieve transmitter efficiency. When the omission was observed by the inspector and pointed out, it assisted the technician to complete his assignment, air test the transmitter and obtain much needed rest. Another inspection disclosed a previously unnoticed condition which had it not been found, pointed out to the licensee and corrected, could have resulted in a disastrous fire.

Licensee's replies to citation forms are studied by the Engineer in Charge of the district. If assured by the licensee that adequate corrective measures have been taken, the matter is retired to the station's files in the district office. More serious discrepancies and those which have not been corrected are referred to the Washington office for further study and appropriate action. It will be seen therefore, that prompt correction of discrepancies by the station owner or his technician is very desirable, avoiding un-

necessary correspondence, or more stringent action.

Whenever possible the inspecting engineer has the technician or operator place the station's transmitter in operation to observe its characteristics. Often too, frequency measurements are made to determine whether the station is maintaining its frequency within assigned tolerances. Operation of station equipment should be by its operator or other licensed representatives of the station owner. Our inspectors do not, in general, operate the equipment themselves.

Access to the station, for purpose of inspection, is specifically required by the Rules. Occasionally, however, an inspector has some difficulty in locating a licensee's representative to open the station for inspection or even to find the key to the station. This happens frequently when private aircraft stations are being inspected at airports. It is important that stations which do not have operators in continuous attendance establish procedure so they may be made available for inspection upon request and a key should always be in a place where it can be provided when needed.

So far I have made no mention of the original vehicular radio station. I am advised that your group includes ships in the vehicular category and I am happy to give ship inspections a prominent place in this discussion. Actually, the first radio inspections made in this country were on shipboard, starting in July 1911 when offices of the Radio Service, Department of Commerce and Labor were opened for this purpose at New York and San Francisco. In those days the flashing spark denoted the radio transmitter. It was capable of communications over relatively short distances, as compared with those which we are able to cover today. This limitation resulted in part from the use of the rather insensitive magnetic crystal or electrolytic detectors in use and the less efficient spark transmitter.

The need for ship radio stations was made abundantly evident by the long record of ships which were not radio equipped, which sailed from various ports of the world and were never again heard from. On June 24, 1910 the international requirements for radio communication went into effect for passenger carrying vessels. Beginning in 1912 emergency equipment, in many instances a ten inch spark coil operating on batteries, was installed to permit the sending of distress messages even though the ship's electrical system was wrecked by flooding or other damage. Two or more licensed radio operators were required for certain passenger vessels. Every captain of a radio equipped ship was required to have a message sent over a distance of at least 100 miles, giving his position and the statement that the radio equipment was effective over that distance.

A book in my office, printed in 1916, contains about 20 pages of brief entries listing ships of various nations which were involved in disasters at sea up to that date and how the rescue of their passengers and crews was made possible by the use of radio communications or "wireless" as it was then called.

Inspections of ship radio stations have kept pace with the advances in the art, and the added requirements for safety agreed upon at the various International conferences and the Safety of Life at Sea conventions. Where formerly the ship radio station was equipped with only the barest necessities in the way of spare parts and tools or none at all, it is now required that these be furnished with such completeness that practically any predictable breakdown in the radio apparatus can be corrected by the operator. Also, during this time the emergency equipment is available for communication in time of need.

In addition to inspecting the main equipment, including the main transmitter, motor generator, main receiver, auto alarm, direction-finder, and main antenna, the emergency equipment receives a thorough going over including checking the emergency power supply for the required number of hours at the required load in amperes to be certain that it will function efficiently at any time. The required spare parts, including brushes for the motor generator, spare tubes, spare antenna gear, tools, test meters, portable electric light, fuses, batteries, hydrometer, soldering iron, and the spare bulbs for the emergency light, to mention but a few, are all checked to see that the installation is ready for any eventuality. Such details as the placement of the emergency light with relation to the main and emergency radio operating controls and the radio station clock and other spare parts are looked into.

From what I have told you, you will appreciate that the Commission and its predecessor agencies, the Radio Division - Department of Commerce, and the Federal Radio Commission have left no stone unturned to assure safety of life and property by means of reliable radio communication to passengers leaving United States ports on United States or foreign passenger carrying vessels, for similar, though less precise inspections are made on some foreign passenger ships upon specific request. Likewise, careful inspection of the radio equipment on freight carrying vessels above 500 tons gross are made to guarantee to the men who go down to the sea in ships that their lives and property also will be safeguarded.

Demonstration of the apparatus, display of the spare parts, and proof by frequency meter measurements that the ship's frequencies are with-

in tolerance is a function of the radio service agency which maintains the ship's equipment. Ideally, the service technician makes a preliminary inspection during which he satisfies himself that all conditions and requirements of the ship installation are met after which he communicates with the Engineer in Charge of the port office which is about to make the detailed inspection.

When our engineer finds the ship radio installation in full compliance, appropriate certification is made so that the ship may receive its Radiotelephony or Radiotelegraphy Certificate, required under international law for oceangoing vessels, or more recently by the "Agreement between the United States of America and Canada for the Promotion of Safety on the Great Lakes by Means of Radio" in the case of vessels navigating those waters.

The type and number of the operator license/s are made a matter of record by the inspector. At this time the inspector also carefully reviews the radio station logs maintained by the operator/s. If on a U. S. passenger carrying vessel there would be at least two operators, if on a freighter there may be one operator and an auto alarm, and the operator must show his hours of watch, what signals were heard, when the auto alarm was placed in and out of service, if there were auto alarm calls, if distress, urgent or safety signals were heard, messages sent and received, as well as daily tests of the radio equipment; and he must also show, daily, the condition of all batteries used in the operation of radio equipment.

The log must also show the results of tests of the lifeboat radio equipment which, if required to be on board, must be maintained in a state of complete readiness for use at any time.

Summarizing

During Fiscal year 1954, which ended last June 30, our engineers made a total of 3,324 ship inspections, 533 inspections of broadcast stations and 6,622 inspections of stations in other categories, including those in air and land transportation. These are considerable reductions from the figures for previous years, due to budget limitations, and represent only a sampling procedure in some cases.

I believe the Commission's records show that there are over 600,000 radio stations, of all kinds, licensed in this country, of which approximately 50,000 are commercial and pleasure vessels of various types.

If I may impose some more statistics on you, I might add that there are over 800,000 licensed radio operators of one class or another and that nearly 180,000 new licenses were written last year. Apparently, 70,000 operators died, got married (we do have thousands of lady operators) or went into seclusion as the net increase in valid operator licenses was only 112,000 for 1954.

In closing, may I sum up the purpose and goal of the inspection program as one designed to aid every station owner to operate his station for the maximum benefit to the public while yet achieving efficient communications in his own behalf. When our engineers find that improvements should be made in equipment or operating procedures due to lack of compliance with statute, rule or treaty the licensee is promptly and politely informed to that effect so that corrections can be made.

Our engineers would rather find a station complying in all particulars than to find it technically deficient or operated haphazardly. No one likes to have to point out faults to another, but if we are to have efficient communications in our crowded radio frequency spectrum it must be done and our engineers are the boys who can and will do it.

Please give them your full cooperation, they will appreciate it and I can promise you they will in turn cooperate with you to the fullest extent within their power.

OF COMMUNICATIONS ENGINEERS, MOBILE RADIO, MANAGEMENT AND SEALING WAX*

Jeremiah Courtney
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When your Program Chairman, Mr. Keleher, asked me to talk with the Boston Chapter of the Professional Group on Vehicular Communications of the Institute of Radio Engineers --wow-- I tried to discourage him. I told him I had worked at many jobs but had never tried to be an engineer. I confessed that I hadn't even been admitted into that growing number of lawyers who, on the slightest provocation, will whip out a big slide rule to make a complicated calculation.

Mr. Keleher replied that my remarks would furnish a desirable bridge between management and engineers. I didn't understand this, but I was flattered. The only people I "manage" are three secretaries; and anyone who tries to keep three gals busy knows who's running who. (Could we leave that who, please?)

I then though I might discourage him by saying that my remarks were often not of the sugar-coated variety, my theory being that the alert mind is always critical, and with the rest we shall not bother. Even this didn't stop Mr. Keleher. So here I am.

I guess I am here for another reason, too. Engineers have been telling me things all my life. Anytime a group of engineers wants to hear me, that's it. Now that's not a case of Bulldog-Drummond-strikes-back. I mean it very humbly. I really don't think there's a communications lawyer in the business who doesn't owe a tremendous debt of gratitude to some engineer or engineers.

In my own case, even during busy World War II days, E. K. Jett, when he was Chief Engineer of the Federal Communications Commission (later Commissioner and now Vice-President of the Sun Papers radio and TV properties in Baltimore), would often take time out to explain some radio engineering principle or situation to me, generally after hours. I still remember his explanation of the way power can affect the theoretical limitations of line-of-sight radio frequencies. He took a flashlight from his desk, turned off the room lights, and focused it against the side of his desk. Theoretically, the light rays couldn't illumine the top of the desk; but they splashed over. And ever since then I've had a great respect for the ability of line-of-sight frequencies to get around obstacles. I might add that I have since seen some "book" engineers equally respectful in reviewing the operating results of particular line-of-sight installations.

On one particular deal for the Board of War Communications, Phil Patton, then an FCC common carrier engineer and now Vice-President of Lenkurt Electric Company, gave me a primer on how our nation-wide telephone and telegraph communications plants work. It lasted for 30 consecutive nights. That count is accurate, gentlemen; our wives kept it jointly.

Joe Wofford, while he was at the FCC and before he became an outstanding systems consulting radio engineer in Houston, did the same for me in the industrial mobile radio field. And the list of former and present FCC mobile radio engineers who have drawn diagrams for me -- that is the only way you can explain things to a lawyer -- is just too long to spell out here but I can, and do, acknowledge my lasting indebtedness to all of them. And also to the industry engineers like Tom Warner of National Bus Communications who have taken up the burden of continuing my education since I left the FCC.

It's just as well I have had those post-graduate sessions because I've noticed a gradual change during the last few years in the people who write me. In the beginning it was generally house counsel who didn't want to get into something they didn't know a thing about, like radio. Now the correspondence is signed by people bearing titles like Chief Engineer; Construction Engineer; Plant Engineer; Mechanical Engineer; Engineering Representative; Chief Draftsman; Vice-President, Engineering; yes, and sometimes even, Radio Engineer.

No question about it, the engineers shall inherit the earth because it's getting too complicated to run without benefit of an engineering background. Few indeed are the industries which can any longer be described, as some one once described the oil industry, as a small body of business men entirely surrounded by lawyers. The fellow who said that was not

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a lawyer but even a lawyer may perhaps be pardoned from questioning whether the ultimate inheritance of engineers has not been anticipated somewhat within the Safety and Special Radio Services of the Federal Communications Commission where the Chief of the Bureau and every single Service Division Chief -- Amateur, Aviation, Land Transportation, Industrial, Marine and Public Safety -- is an engineer!

Now I don't mean that at all critically. All I mean to suggest is that occasionally engineers may feel themselves confined within existing limitations and I will be specific and say in this case that the limitations I refer to are specific frequency boundaries. A lawyer, on the other hand, may be able to look ahead and see some possibility for alleviating the rigid limitations within which the engineer would accomplish his work, and without hurting any other user. Constructive use of precedent is the term the lawyers apply to this extension of a sound precedent to a new or novel set of facts. The combination of able engineers and able lawyers working together may thus perform prodigies of public service, while either one working alone might fall far short of the means for expanding, or avoiding a contraction, of mobile radio usage.

Of one thing, I am convinced. Just as a lawyer's horizons may unquestionably be widened by the contributions of engineers, so may an engineer's total effectiveness be increased by rubbing shoulders with lawyers. Lawyers have special gifts too, of selection, focus and presentation, among others. The particular gifts of each group may be welded together to arrive at a common goal, if working contact between the two is established and maintained in a climate of mutual respect.

The dangers of a narrow, engineering approach to communications problems are perhaps nowhere better illustrated than in the area of mobile radio sales. Too many mobile radio sales programs -- and important ones -- have been attempted in the past without first casing the industry's communications needs.

Truck radio usage almost expired five years or so ago with the experimental program of Highway Radio, Inc. in Chicago. The American Trucking Association spent some $30,000 plus in that experiment trying to find out what radio had to offer for the trucking industry. They found out just about nothing because the wrong kind of trucks were equipped with radio. They put the mobile installations on milk trucks, for example, that collected the milk in rural areas and then shot on down to Chicago. The drivers knew where they were going to collect the milk and they knew where they were going to deliver it. They needed radio communication with their headquarters office in Chicago about as much as I do driving my car to work every morning. How different the results would have been if the installations had been concentrated in the trucks of the regular common carriers. These trucks go about the City of Chicago collecting less than truck load quantities for delivery to a central terminal. The constantly changing pattern of shipper demands cannot be predicted, and this naturally makes radio indispensable to efficient operations.

The use of radio by inter-city buses also narrowly escaped a similar fate. Their initial experimental installation consisted of a single land station serving several bus lines operating in and out of Chicago. Let me now quote from a comment recently filed with the Federal Communications Commission by Mr. Warner of National Bus Communications:

> "Experience has shown that the maximum returns from the use of radio by the intercity motor bus industry are only gained when a substantial number of the major terminals and buses of any division of an intercity carrier are radio-equipped. A single land station is of practically no value in controlling the intercity movement of buses between major terminals."

Have these early sales errors been eradicated? I would say that the same error is not being repeated in old fields but that it continues in new fields. For example, I recently participated in a common carrier trucking symposium in Chicago that I don't think could be improved upon from the sales point of view. I had been invited to explain the presently complicated frequency situation. The communication needs of those regular common carriers had been figured to a decimal point. The sales engineers knew what the carriers needed in the way of communications; they showed what radio would contribute to the carriers' operations; and the costs of radio were most impressively and accurately poised against the costs of the radioless trucking operation. I am sure many a trucker's eyes were opened as to what radio could do for <u>his</u> operation. Those eyes were opened wide not because the speaker had an amateur or first or second class radiotelephone license but only because of the way that radio use was related to the trucker's daily operational problems.

Incidentally, they even had an industrial psychologist at that symposium. In addition to dealing with lawyers, do you vehicular engineers have to deal with industrial psychologists, too? Though it

sounds like a fate worse than death, I regret to say the answer is yes.

The answer is yes because if you don't explain the introduction of radio to the employees you can get a very bad labor reaction that will defeat all the contributions your engineering skill has to offer. Believe me, there is just no way to make a truck driver use radio. What engineering answer have you for the truck driver who explains to the irate manager why he couldn't reach him by radio: "I tried to use the radio earlier in the day, boss, but the blankety-blank set wasn't working so I turned it off."

The engineering answer to that problem of equipment mal-function is supplied by the industrial psychologist. He says--take great care to explain the reasons for the introduction of radio before the actual installation is made. The explanation should be given in terms of the increased significance of the employee's role by reason of the flexibility of operations that accompanies his control of a radio-equipped truck; in terms of the elimination of that feeling of frustration in being required, without radio, to go all the way back to the place he just came from; in terms of his availability to management in the event of a personal emergency such as his wife's anticipated maternity; and in terms of management's availability to him in the event of personal emergency such as accident or breakdown as well as in assisting in the difficult decisions that each day brings to the driver.

This Chicago trucking symposium convinced me that the old sales errors are not being repeated in the established fields. But I think they are still being made in the newer fields. I have heard many, many manufacturers, for example, complain that they are showing the mobile radio sales engineers how to use radio; the engineers are not showing them how radio may be employed to advantage in their operations.

The manufacturing companies are not slow to compare this situation with their experience in the use of I.B.M. equipment. In introducing I.B.M. equipment, the salesmen stimulated the imagination of their manufacturing company purchasers in the many unknown uses to which their equipment could be put. Very little idea-stimulation has characterized mobile radio sales in the manufacturing field, although the field is tremendous, or would be with adequate frequency provision.

I was invited here particularly to discuss the Petition which the Committee on Manufacturers Radio Use recently filed with the FCC for additional frequencies in the so-called Citizens band. I think your group is to be congratulated on your awareness of the profound significance of the radio use of the manufacturing industries of the country. I have participated in the establishment of many new radio services but I assure you that I regard my connection with the continuing effort of the manufacturing companies to establish a new radio service as far and away the most significant association I have had since devoting myself to mobile radio matters. I have, in fact, alluded to past sales errors in other fields only because I sincerely hope they will not be repeated in any way that will retard manufacturing company radio usage because, if so, the country at large suffers. I am therefore sorry that I feel lacking in the necessary perspective, even if it were appropriate now, to discuss the merits of that Petition against the occupation that is being made of the Citizens band.

There is, however, one non-controversial aspect of the Petition in which you may perhaps be interested because of its general applicability to the subject of our mutual interest. I think you will better appreciate what I have to say if I sketch in the background details. Herbert E. Markley of the Timken Roller Bearing Company and Victor G. Reis of the Bethlehem Steel Company, Chairman and Vice-Chairman, respectively, of the Committee on Manufacturers Radio Use, were sitting in my office dictating our Petition. We had reached the point where we wanted briefly to explain the function of mobile radio in manufacturing operations. How account for the extraordinary reception that radio is receiving by the manufacturing companies using it?

I said that I could tell them why taxi operators and taxi drivers "love that radio". The taxi driver loves that radio because he makes more money with it than without it -- the simple, nothing succeeds like success test. The taxi operator loves radio for less obvious reasons although he, too, must examine his profit-and-loss statement with a high degree of care.

I should say right here that Washington and New York are not normal taxi cities. But in every other city that I know of, the taxi operator spends his life building up his "call" business. And what happened, before radio, on a rainy day? The taxi driver had plenty of pick-up business; no need for him to call the taxi office and get a pay-load. Result: the taxi operator had to disappoint the people who called him for service when they most needed it, in bad weather.

With radio, the whole situation has changed since the taxi operator can now

reach his radio-equipped cabs and send them to fill the customer calls. Giving service to regular customers and others when needed builds the business. Failure to give service under such conditions kills it. The driver living for the day may ignore the call business; the operator whose business growth and very existence turns on dependable call service cannot and does not wish to ignore call business. In short, radio has permitted the taxi operator to run his business as he -- not the drivers -- think it should be run. The result is better public service.

Well, we all agreed that was not quite what accounted for the expansion in number of mobile units that invariably follows a manufacturing company's initial installation of a few mobile units. We batted the subject around, went through five or six drafts, and finally came to what I regard as a universally acceptable explanation of the high importance of mobile radio to all users. Here is our definition of the function of mobile radio communications in manufacturing operations.

> "The primary function of the managers of any enterprise is the projection of themselves to the greatest extent possible into every important part of the whole process. This has been true from the earliest times in man's productive activities. The one-man farm was operated ideally by the owner because he had direct control of the whole operation. When he engaged a hired hand to share the work and increase the productivity of his farm, he became a manager. As such, his problem was to get the work of the hired hand done as he would do it himself. The solution for him was easy: oral instructions, which could be altered quickly during the day as required. Now a manager often is responsible for instructing and supervising hundreds of employees, but his basic problem in directing a working force remains with him -- he must still try to get the work done essentially as he would do it himself or as he would wish it done; even though it is physically impossible for him directly to oversee all parts of the operation.
>
> "The difficulties of the problem are intensified in modern industry when operational areas are large and scattered and production procedures are complex and interdependent. Rapid communication is an important element in overcoming the difficulties. Through the years many well-known and efficient transmitting methods have been developed and industry has made full use of the telegraph and the telephone and other fixed wire-line facilities. Radio, however, is used when wire-lines cannot be used at all, as in the operation of mobile vehicles, from which it is obviously impossible to trail wires; it is also used in certain kinds of operations where wire-lines would be cumbersome or hazardous or uneconomical, and in the activities of mobile working crews in locations where only a portable communications system is feasible or desirable. In all those cases radio communications permit more effective disposition of vehicles and personnel, which in turn results in substantial conservation of machine-hours, man-hours and vehicle-hours, or, in short, lower costs of production."

I firmly believe that the use of radio in manufacturing operations -- and I don't mean for general transportation purposes but as it is actually integrated into the production line -- holds out almost limitless possibilities, given sufficient frequencies. I have discussed this subject at some length with Mr. E. M. Burke, Construction Engineer, Bethlehem Steel Company, Shipbuilding Division, and I quote from one of his recent letters:

> "It is a personal observation of mine that shipyards, particularly those which have a large portion of the various operations involved in ship construction on an incentive basis, will have unit prices for the various operations very closely standardized. I refer to steel fabrication, welding, painting and even other outfitting trades. In other words, the management heretofore could tell exactly the price per ton for processing steel plate and shapes from the raw stock stage to the erection stage. The labor cost of material handling, which amounted to as much as 65% in the cost per ton of steel erected, was an item which was accepted as an inevitable overhead charge not subject to analysis.
>
> "We have advanced from that stage through an appreciation of what is possible to realize in the improvement of material handling methods by the use of packaging standards, material handling equipment and storage space utility. As an item of material handling equipment mobile radio has contributed enormously. It really is the most vital factor in the control of production costs in that it is the means whereby a Production Manager can establish

a production schedule with a reasonable possibility of having materials arrive and be taken away in the time allotment included in the production schedule.

"Heretofore, incentive rates could be definitely established for all the manual elements involved in any stage of process, but the final cost of the processing at the several stages had to include an allowance to the workman himself for delays to him while he was waiting for material. Such allowances can now be eliminated through the versatility of mobile radio, as Supervisors can immediately make known to proper authorities the material shortages, and prompt dispatching can correct the situations.

"This transition from catch as catch can material handling to precise scheduling is not necessarily a completed accomplishment in our yards, but there has been a tremendous improvement.

"One of the most valuable improvements resulting from the mobile radio is the new attitude of personnel towards material handling. More lifts are being made with less equipment and, seeing this service improve, personnel seem to be more material handling minded. As a consequence, less storage space in critical areas, such as aboard ship and in shops, is required for the storage of material ready to be installed or processed. Supervisors allow less lead time because they can rely on established schedules for material delivery."

For the doubting Thomases, if any there be, some chapter and verse citation may be in order. In any large company, one department will frequently operate independently of the other. Each department knows what its material handling unit requirements are but they have normally been calculated in terms of urgent requirements. Without radio, the only way a particular department could be sure a handling unit was available when needed was to have plenty of units assigned to its independent use.

To describe this system of operations is to condemn it. But there was no satisfactory answer to it before radio because any department with permanently assigned units would be opposed to letting them go, whether or not they were idle most of the time, because it was difficult to locate the units, once beyond their control, for later lifts. Results: wasted equipment and manpower.

How about the handling requirements of departments not having assigned units? Were their shipping problems well handled without radio? To describe the method employed there is again to condemn it. Shippers in departments not having assigned units might attempt to lure a roving unit - tractor, truck, fork lift or straddle - by hanging colored placards in the vicinity of the shipping area of the department. The color of the placard indicated the type of handling unit required and the success of the system depended upon the initiative of the driver in seeing the job-call. Something like trying to attract an experienced waiter who may or may not want to serve you at the moment.

Of course, shippers <u>in extremis</u> could hail the passing unit or otherwise commandeer it -- while some one else waited. Or the shipper might call the Transportation Department, where the uncontrolled job assignments accepted by the roving units usually meant slow service, or possibly the arrival of a unit as a commandeered unit pulled away. I could go on, but I think the picture of catch-as-catch can material handling to which the radioless manufacturer is condemned is quite clear.

The inauguration of a two-way radio-central dispatch system, however, puts control of all material handling units in the dispatcher, and invariably results in a vast improvement in handling service. Some units may continue to be assigned to departments having considerable traffic, but fewer than before radio. The dispatcher, furthermore, retains control, and may pull idle units for use elsewhere, or may for urgent lifts overrule the department shipper and temporarily reassign a unit.

Requests for service (other than for assigned units) are all cleared by the dispatcher, who knows the location of all handling equipment in the yard. At the time of service request, the dispatcher can determine the relative priority of each call, and assign the units accordingly. He also tries to find "return" trips for the equipment, so that deadhead travel time is held to a minimum. Urgent requests are rapidly filled, as the dispatcher can readily locate the proper unit, and has instant contact by radio.

The success of the radio-controlled materials handling system turns in large degree upon the ability of the dispatcher. He must have a thorough knowledge of the yard layout, the facilities at each shipping point, the capabilities and limitation of the equipment, and the location of all equipment at all times. He must be familiar with the types of materials

handled and with the recommended shipping methods. A calm disposition and ability to sense the true priority of service requests also are great assets.

Radio offering the only assurance so far developed that the right amount of material will be available at the right place at the right time, can any one question the expansion that will occur in manufacturing company radio use as the ingenuity of our brilliant manufacturing executives -- in which our country above all others abounds -- is directed to the improvement of material handling practices?

Again for the doubting Thomases, if any there be, the economic and national importance of what I am about to say cannot be over-emphasized. It is this. In almost all types of manufacturing operations, there is a considerable amount of indirect costs. One of the major elements of those indirect costs is material handling. Other costs of manufacture having become largely standardized, we have reached the stage today where in many cases the only opportunity one manufacturer will have to improve the price of his competitor will be through improved material handling practices.

There is one final thought I would like to leave with you. It really sums up just about everything I have been talking about. Industrial management is now catching up with the rest of the world in the matter of communication by radio. For many, many years ships at sea, airplanes and police departments have been distributing important information and co-ordinating their activities by means of radio communications. Industry in many areas has meanwhile been relying on visual signs, footwork or oral communications or has been without any sort of communications. The ultimate results of the search by manufacturing companies for the application of radio communications in all feasible areas will be the establishment of a phenomenal number of radio systems. The research studies and experimental operations in this field can best be progressed by you people in the audience. You have an unlimited scope for your imagination and inventive abilities and if the job is properly done you will leave a permanent, shining mark on the development of radio systems in industry.